



Santa Fe Institute

**Visual Analytics** & Learning Analytics  
in support of **Data-Driven Decision Making**

Katy Börner, Indiana University @katycns

*SFI Colloquium on “The Complexity of Educational Ecosystems”  
Santa Fe Institute, Santa Fe, New Mexico*

*June 4, 2018*



Santa Fe Institute

# **Visual Analytics** & Learning Analytics in support of **Data-Driven Decision Making**

## **Outline:**

Context

*Data Driven Decision Making*

*Visual Analytics*

*Learning Analytics*

*Embracing Human and Machine Intelligence Symbiosis*

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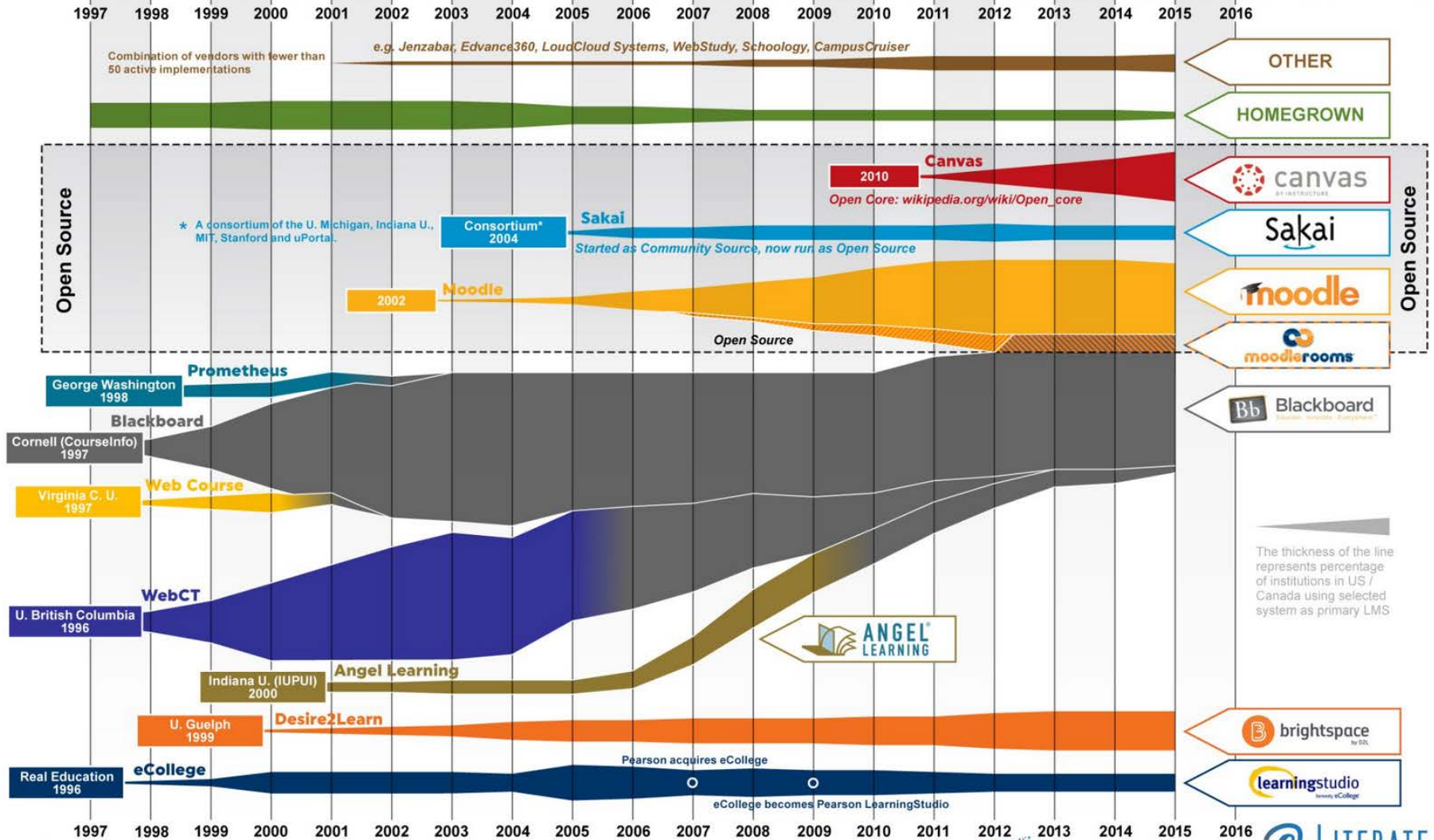
## Context

# LMS Market Share For US & Canadian Higher Ed Institutions

SPRING 2016  
VERSION

LEARNING MANAGEMENT SYSTEM

LEARNING PLATFORM



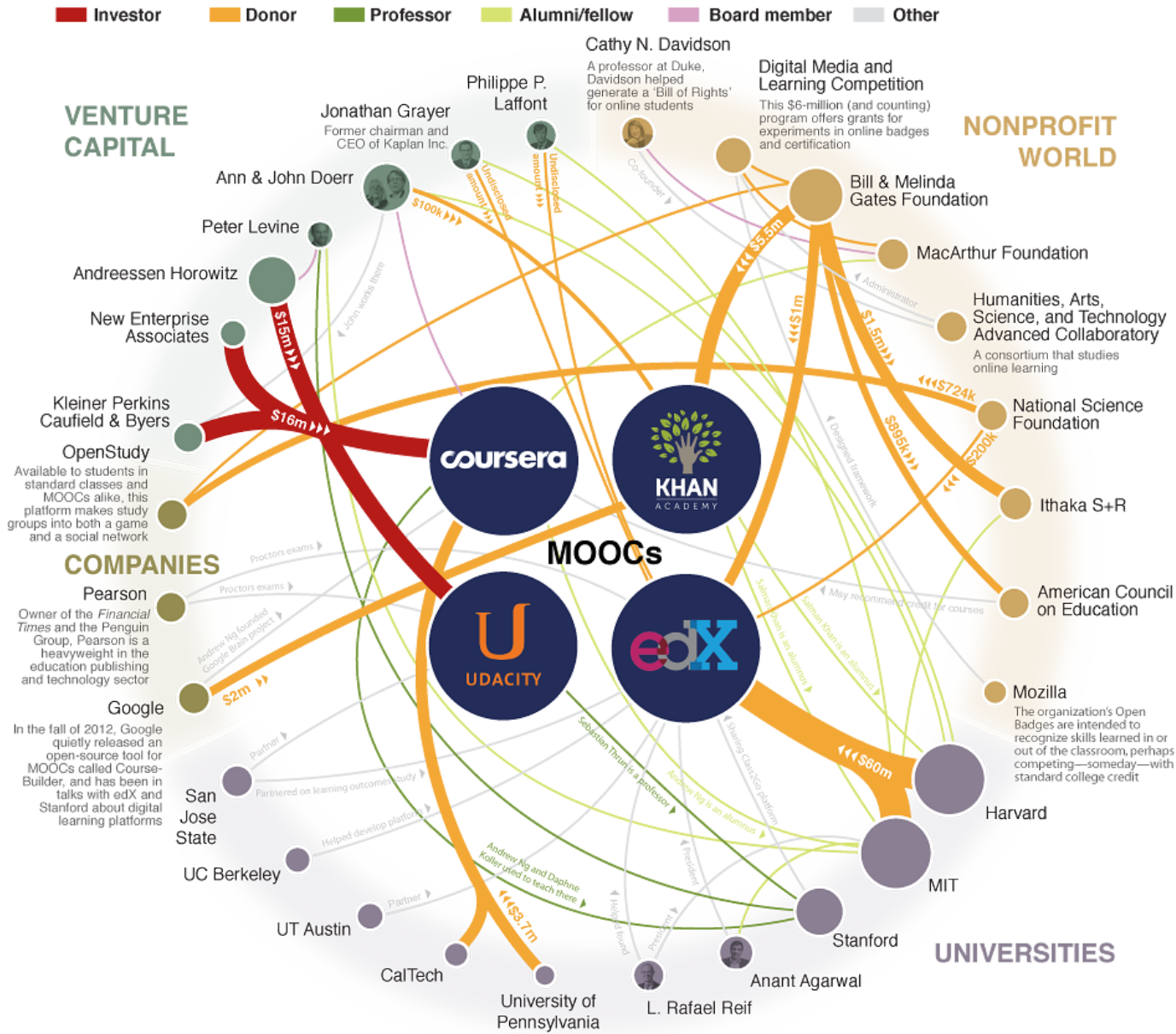
All data from LISTedTECH LMS database under agreement with MindWires Consulting

LISTedTECH

delta initiative

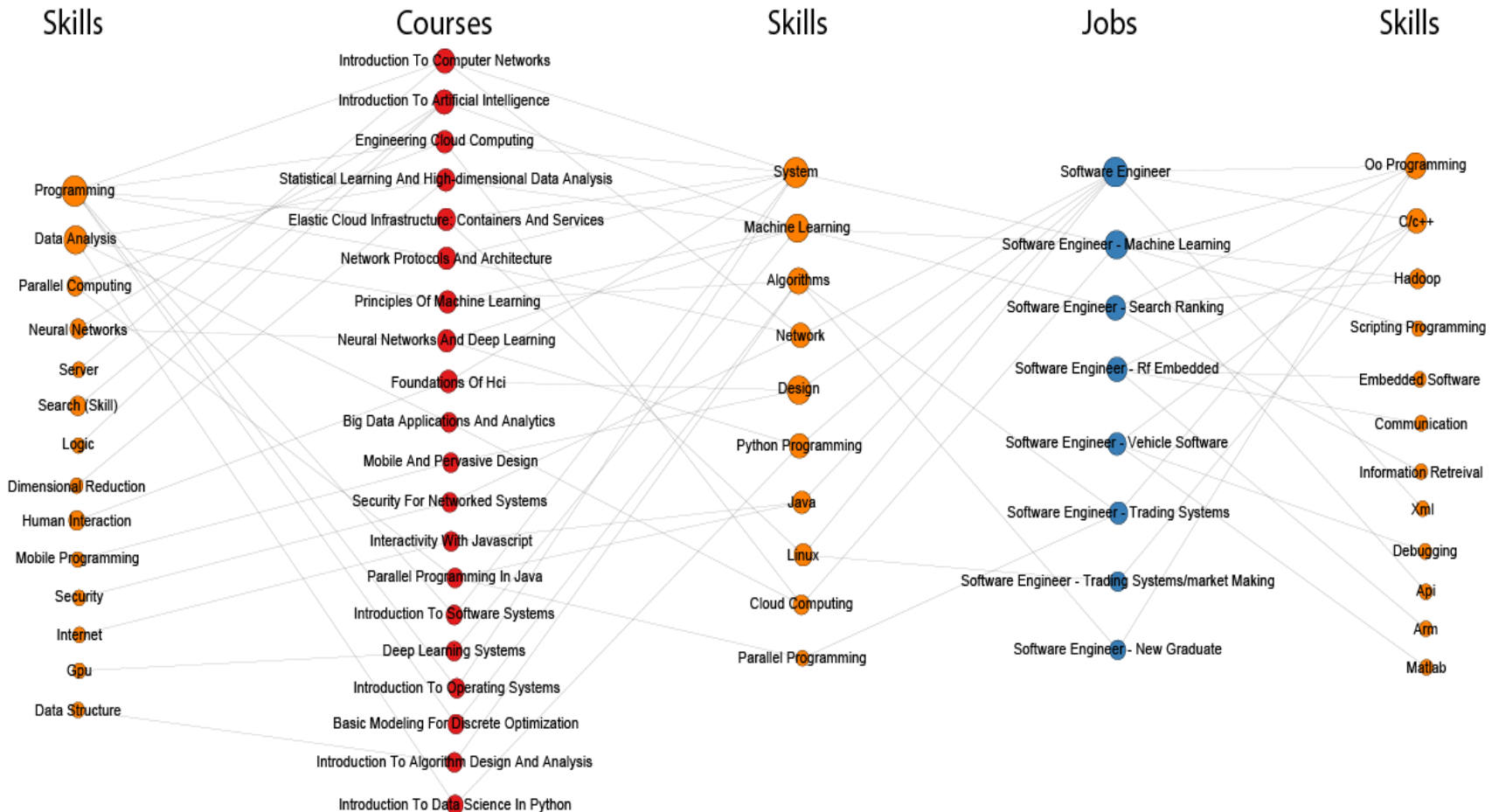
@-LITERATE  
mfeldstein.com

<https://mfeldstein.com/state-higher-ed-lms-market-spring-2016>



# IU Data Science Program: Courses, Skills & Jobs

Katy Börner, Michael Ginda & Xiaozhong Liu, Indiana University

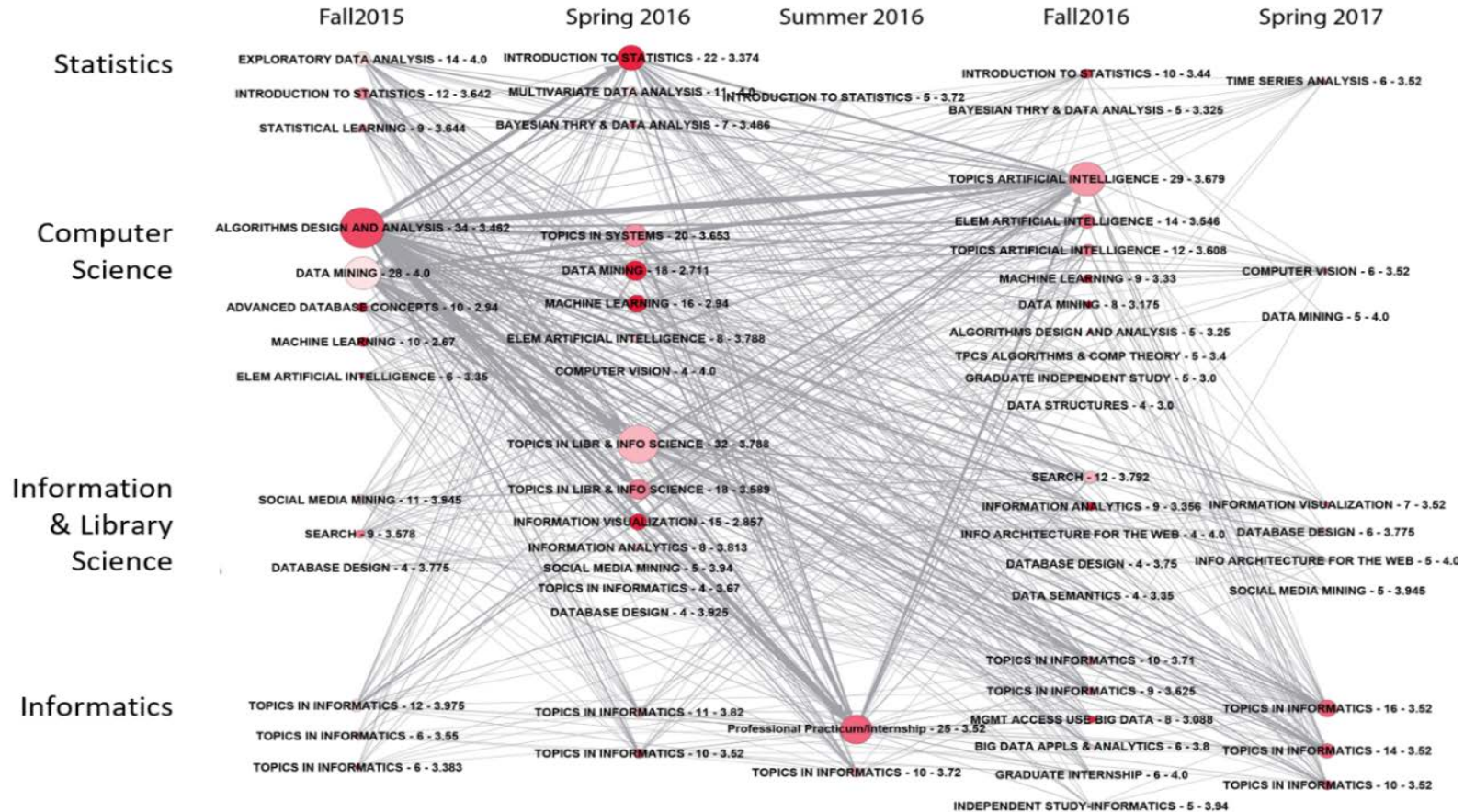


Exemplary set of IU Data Science courses, ‘Software Engineering’ jobs, and associated skills.

Job data was retrieved from LinkedIn and CareerBuilder and course data come from the IU course list. As can be seen, there are many skills (in orange) that are exclusively associated with courses or jobs; however, the skills in the middle interlink courses (in red) to jobs (in blue).

# IU Data Science Program: Student Course Transition Network

Michael Ginda, Kayla Scroggins & Katy Börner, Indiana University



Empower students, teachers, and curriculum committee members to understand and discuss current and desirable student cohorts, key course trajectories, or the (gatekeeper) role that specific courses play. Vertically, courses are arranged into four groups based on the department offering the course. Within each vertical grouping, the nodes are sorted by the total enrollment for the course with highest values on top. Node size encodes number of students enrolled; node color denotes overall GPA for the course.

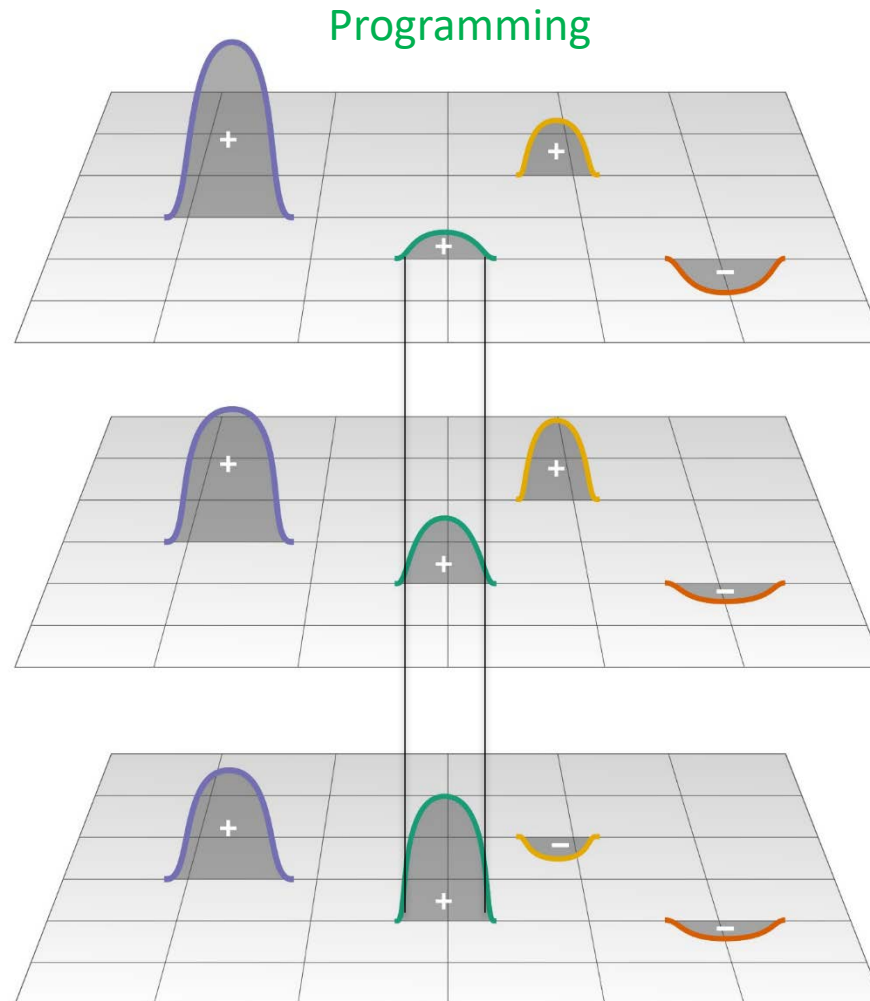
# Science & Technology vs. Education/Training vs. Jobs

Katy Börner, Olga Scrivner, Mike Gallant, Shutian Ma, Xiaozhong Liu, Keith Chewning, Lingfei Wu and James A. Evans

Need to study the **(mis)match** and **temporal dynamics** of S&T progress, education and workforce development options, and job requirements.

## Challenges:

- Rapid change of STEM knowledge
- Increase in tools, AI
- Social skills (project management, team leadership)
- Increasing team size





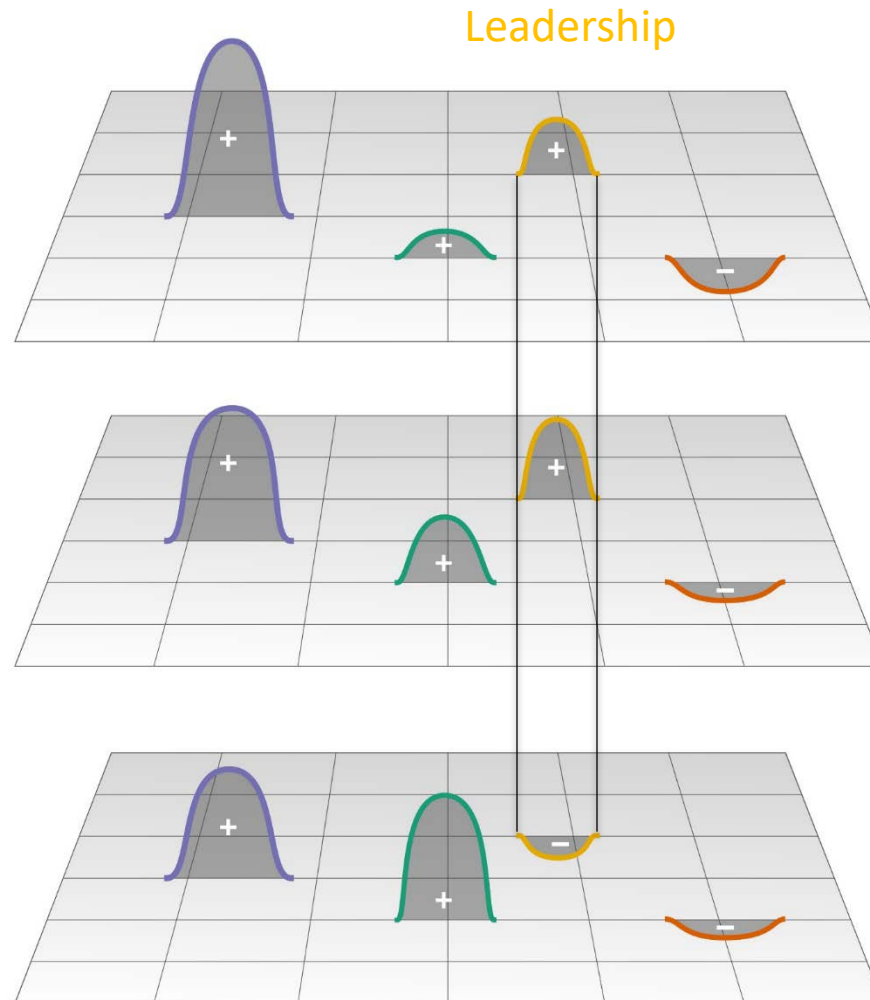
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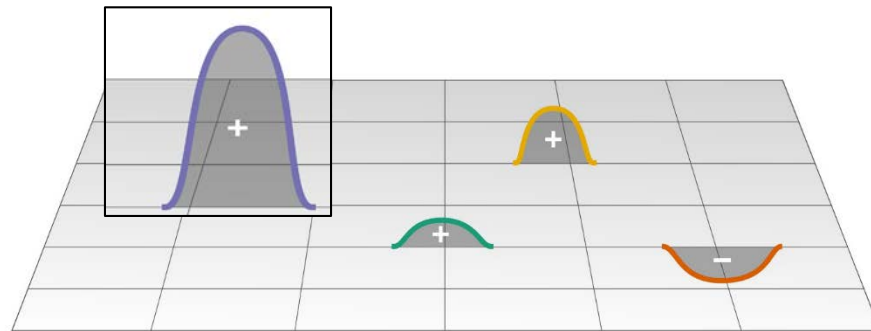


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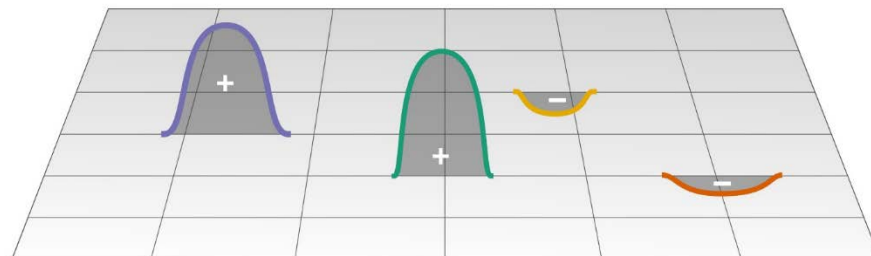
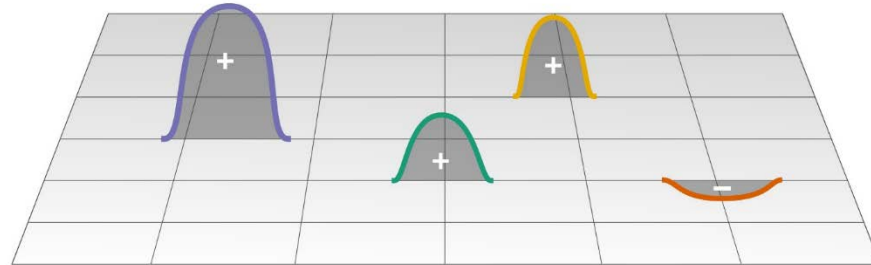
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## Data Science



## Challenges:

- Rapid change of STEM knowledge
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- Increasing team size



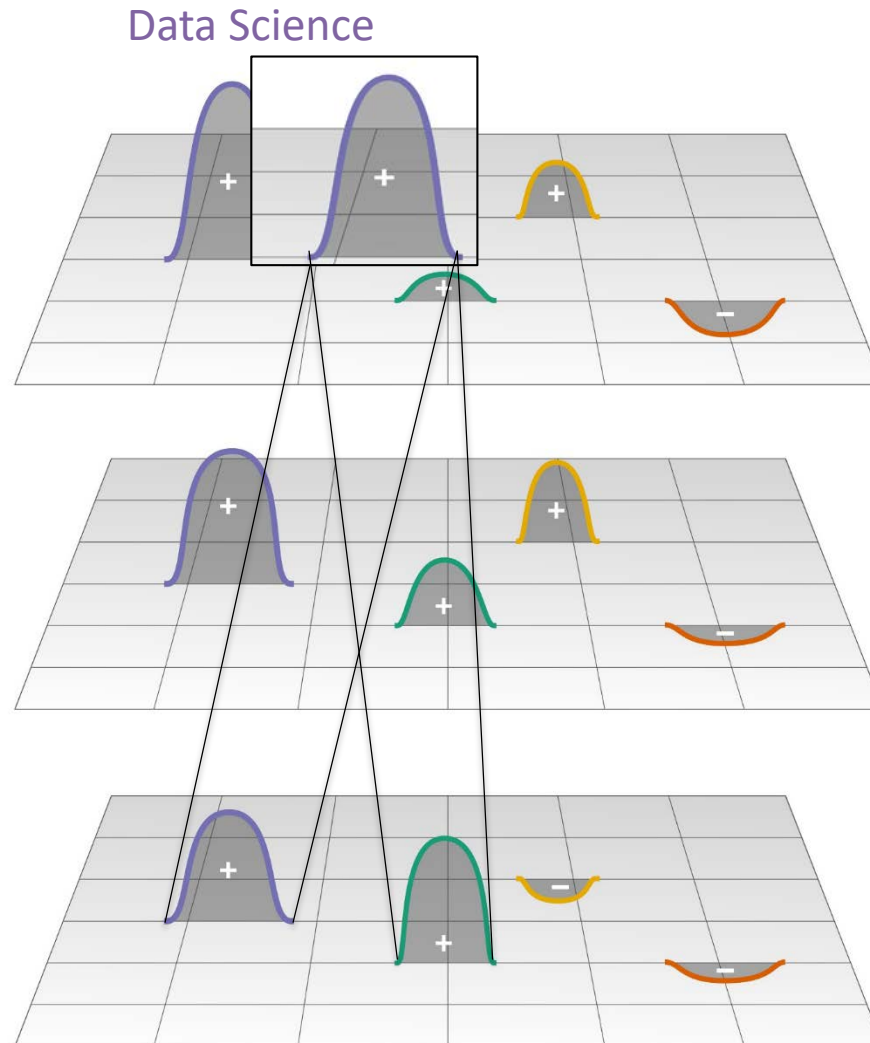
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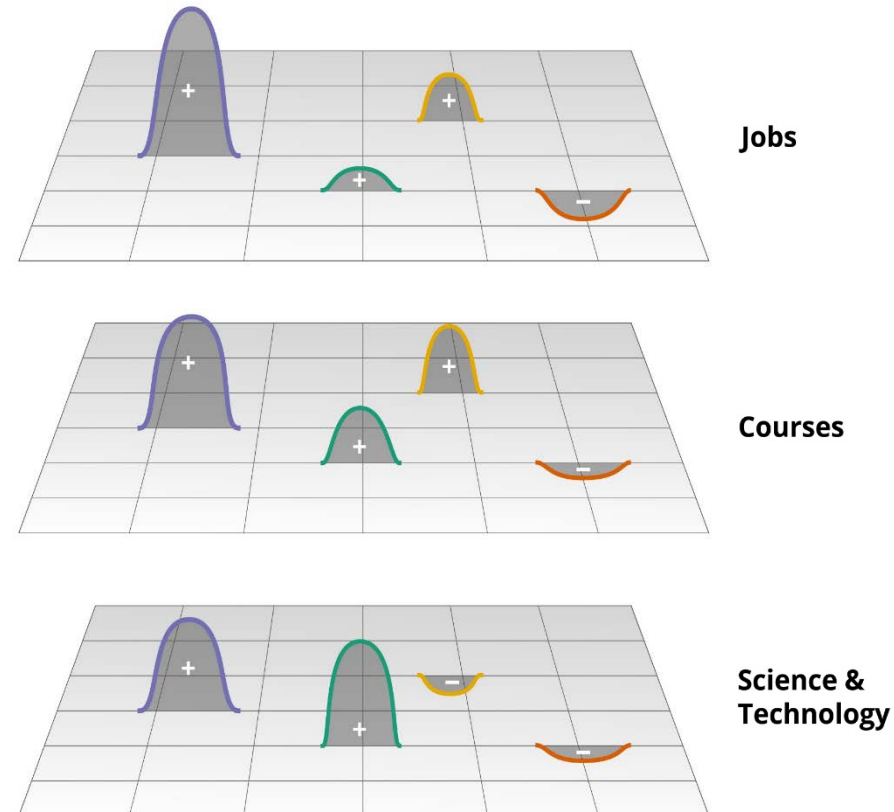


# Science & Technology vs. Education/Training vs. Jobs

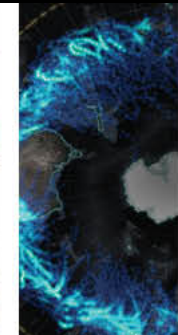
Katy Börner, Olga Scrivner, Mike Gallant, Shutian Ma, Xiaozhong Liu, Keith Chewning, Lingfei Wu and James A. Evans

Study results are needed by:

- **Students:** What jobs will exist in 1-4 years? What program/learning trajectory is best to get/keep my dream job?
- **Teachers:** What course updates are needed? What curriculum design is best? What is my competition doing? How much timely knowledge (to get a job) vs. forever knowledge (to be prepared for 80 productive years) should I teach? How to innovate in teaching and get tenure?
- **Employers:** What skills are needed next year, in 5 years? Who trains the best? What skills does my competition list in job advertisements? How to hire/train productive teams?



**What is ROI of my time, money, compassion?**



## Modeling and Visualizing Science and Technology Developments

National Academy of Sciences Sackler Colloquium, December 4-5, 2017, Irvine, CA

### Rankings and the Efficiency of Institutions

H. Eugene Stanley | Albert-László Barabási | Lada Adamic | Marta González | Kaye Husbands Fealing | Brian Uzzi | John V. Lombardi

### Higher Education and the Science & Technology Job Market

Katy Börner | Wendy L. Martinez | Michael Richey | William Rouse | Stasa Milojevic | Rob Rubin | David Krakauer

### Innovation Diffusion and Technology Adoption

William Rouse | Donna Cox | Jeff Alstott | Ben Shneiderman | Rahul C. Basole | Scott Stern | Cesar Hidalgo

### Modeling Needs, Infrastructures, Standards

Paul Trunfio | Sallie Keller | Andrew L. Russell | Guru Madhavan | Azer Bestavros | Jason Owen-Smith



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## Data Driven Decision Making



# Map of Scientific Collaborations from 2005-2009



Computed Using Data from Elsevier's Scopus



# The EMERGENCE of NANOTECHNOLOGY

## MAPPING THE NANO REVOLUTION

The emergence of nanotechnology has been one of the major scientific-technological revolutions in the last decade and it led to a structural reorganization of major fields of science. Price (1965) showed that fields of science and their development can be mapped using aggregated citations among the journals in the fields and their relevant environments.

The frames to the right show the evolving journal citation network for the years 1998-2003. Distances are proportional to cosine values between the citation patterns of the respective journals. Textual descriptions of key events during the development of *Nanotechnology* are given below each frame. Most notably, leading papers in *Science* and *Nature* catalyzed the breakthrough around 2000.

## CHANGING ROLES OF DIFFERENT JOURNALS

The interdisciplinarity of a journal can be measured using betweenness centrality (BC)—journals that occur on many shortest paths between other journals in a network have higher BC value than those that do not. In the maps, sizes of nodes are proportional to the betweenness centrality of the respective journal in the citation network.

From being a specialist journal in applied physics, the journal *Nanotechnology* obtains a high BC value in the years of the transition, ca. 2001. This is preceded by the "intervention" of *Science*. After the transition, the new field of nanotechnology is established, new journals such as *Nano Letters* published by the influential American Chemical Society take the lead, and a new specialty structure with low BC value journals results.

**1998**

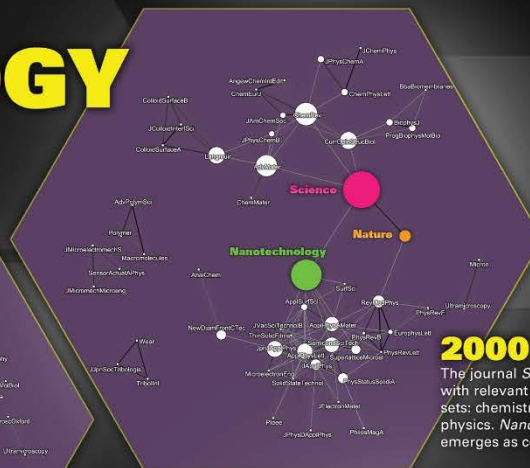
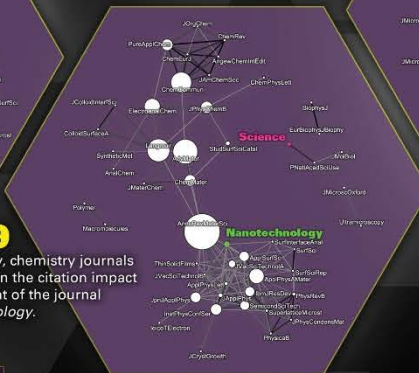
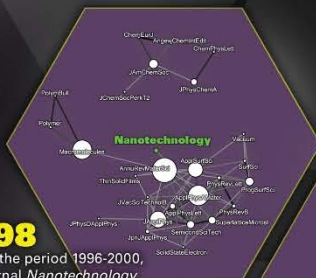
During the period 1996-2000, the journal *Nanotechnology* is part of a group of journals in applied physics.

**1999**

Increasingly, chemistry journals play a role in the citation impact environment of the journal *Nanotechnology*.

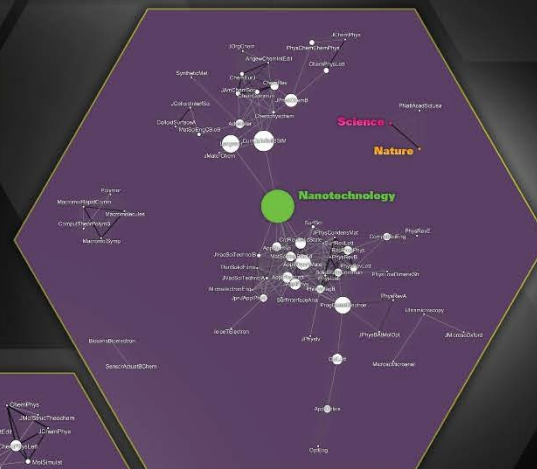
### LEGEND

- *Science*
- *Nature*
- *Nanotechnology*
- *Nano Letters*



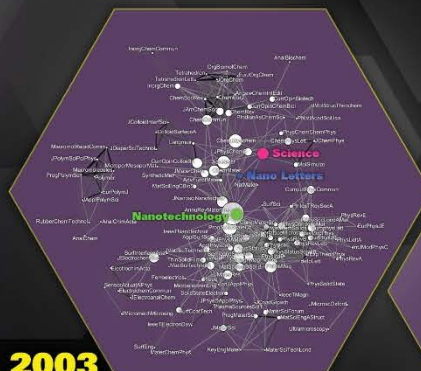
**2000**

The journal *Science* interfaces with relevant journals in both sets: chemistry and applied physics. *Nanotechnology* emerges as core journal.



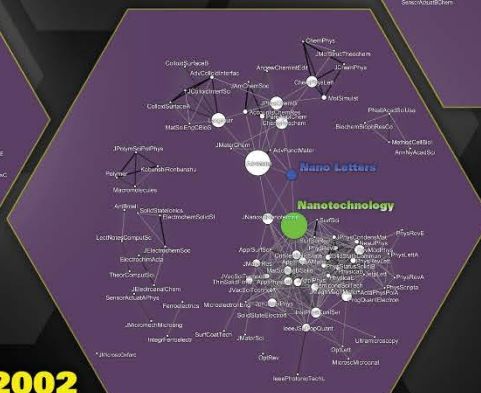
**2001**

The journal *Nanotechnology* now provides the interface between chemistry and physics. The "intervention" by *Science* is no longer needed.



**2003**

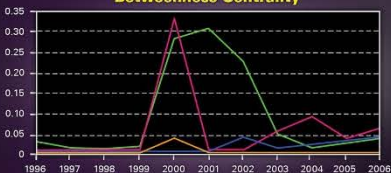
The journal *Science* is relevant in the citation impact environment, but now functions as one of the specialist journals in nanotechnology. *Nanoscience* further develops as an increasingly integrated network of journals.



**2002**

Other journals in nanoscience and technology begin to emerge, and the bridging role of the journal *Nanotechnology* gradually subsides. *Nano Letters* and the *Journal of Nanoscience and Nanotechnology* join the new field of nanotechnology.

### Betweenness Centrality



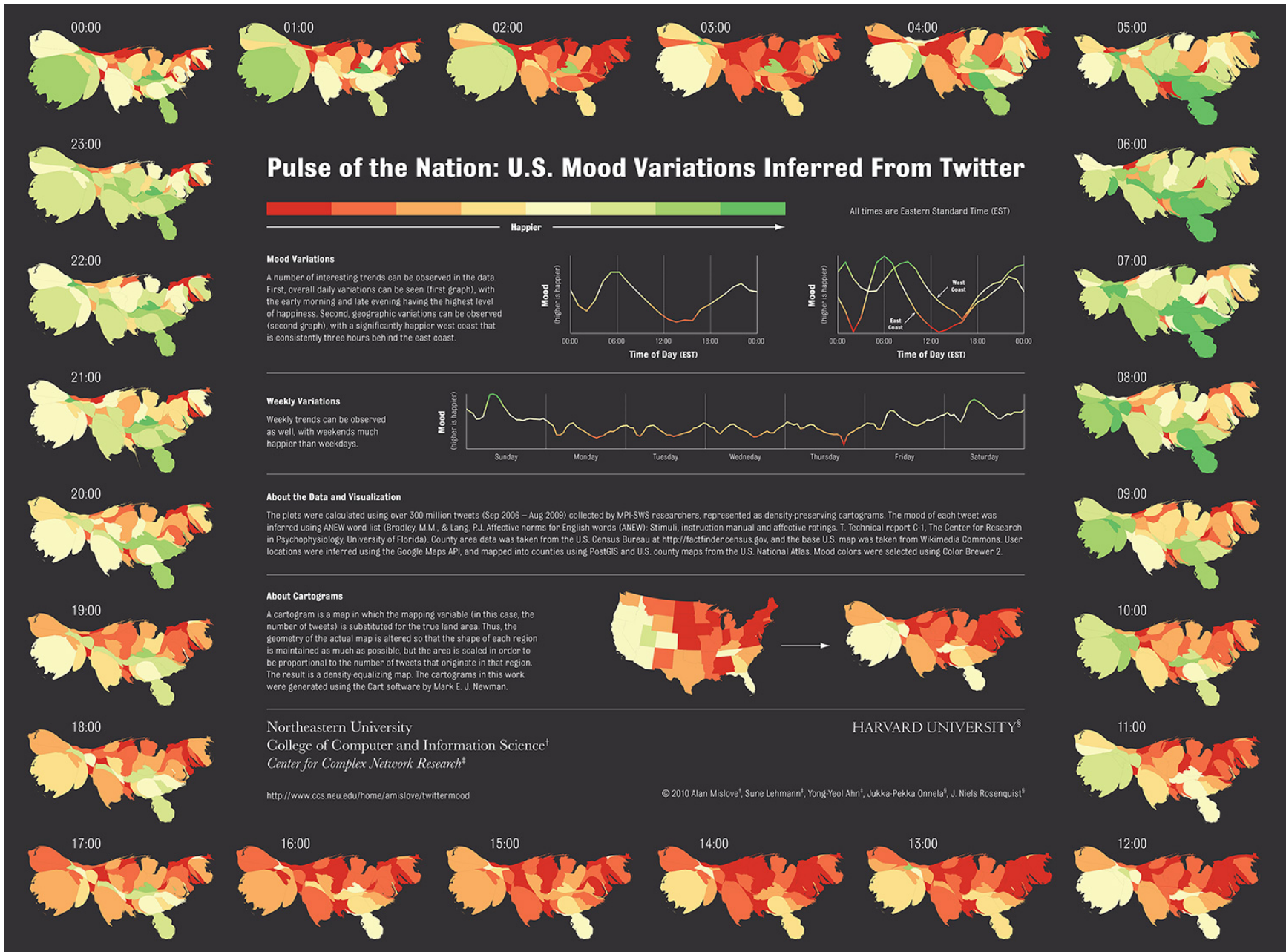
An animated sequence of this evolution is at: <http://www.leydesdorff.net/journals/nanotech>.

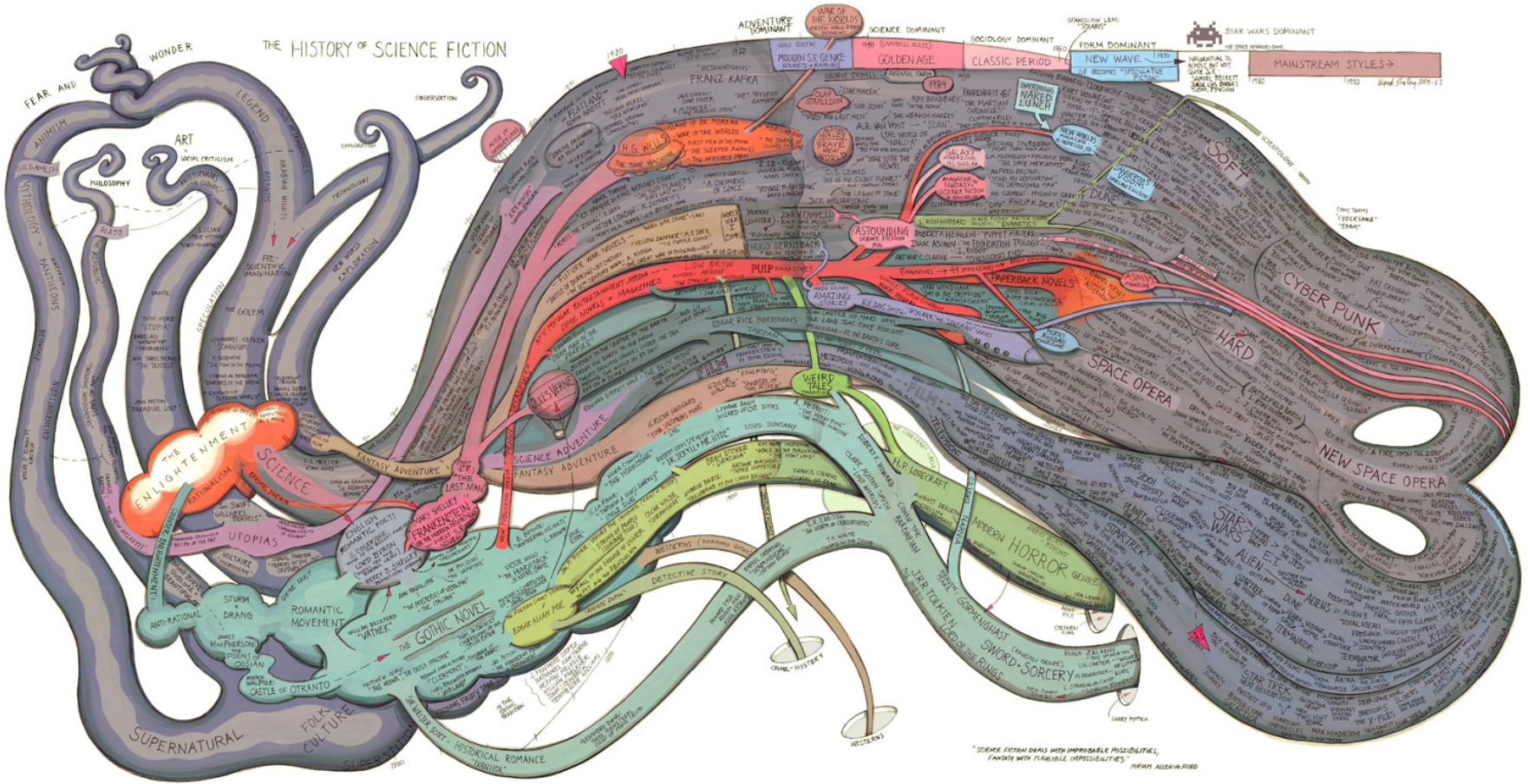
### References

Leydesdorff, L. and T. Schank. 2008. Dynamic Animations of Journal Maps: Indicators of Structural Change and Interdisciplinary Developments. *Journal of the American Society for Information Science and Technology*, 59(11), 1810-1818.

Price, Derek J. de Solla (1965). Networks of scientific papers. *Science*, 149, no. 3683, 510- 515.

Design by Michael J. Stammer and Katy Börner  
Cyberinfrastructure for Network Science Center | Indiana University  
[cns.iu.edu](http://cns.iu.edu)





VII.10 History of Science Fiction - Ward Shelley - 2011

# Check out our **Zoom Maps** online!

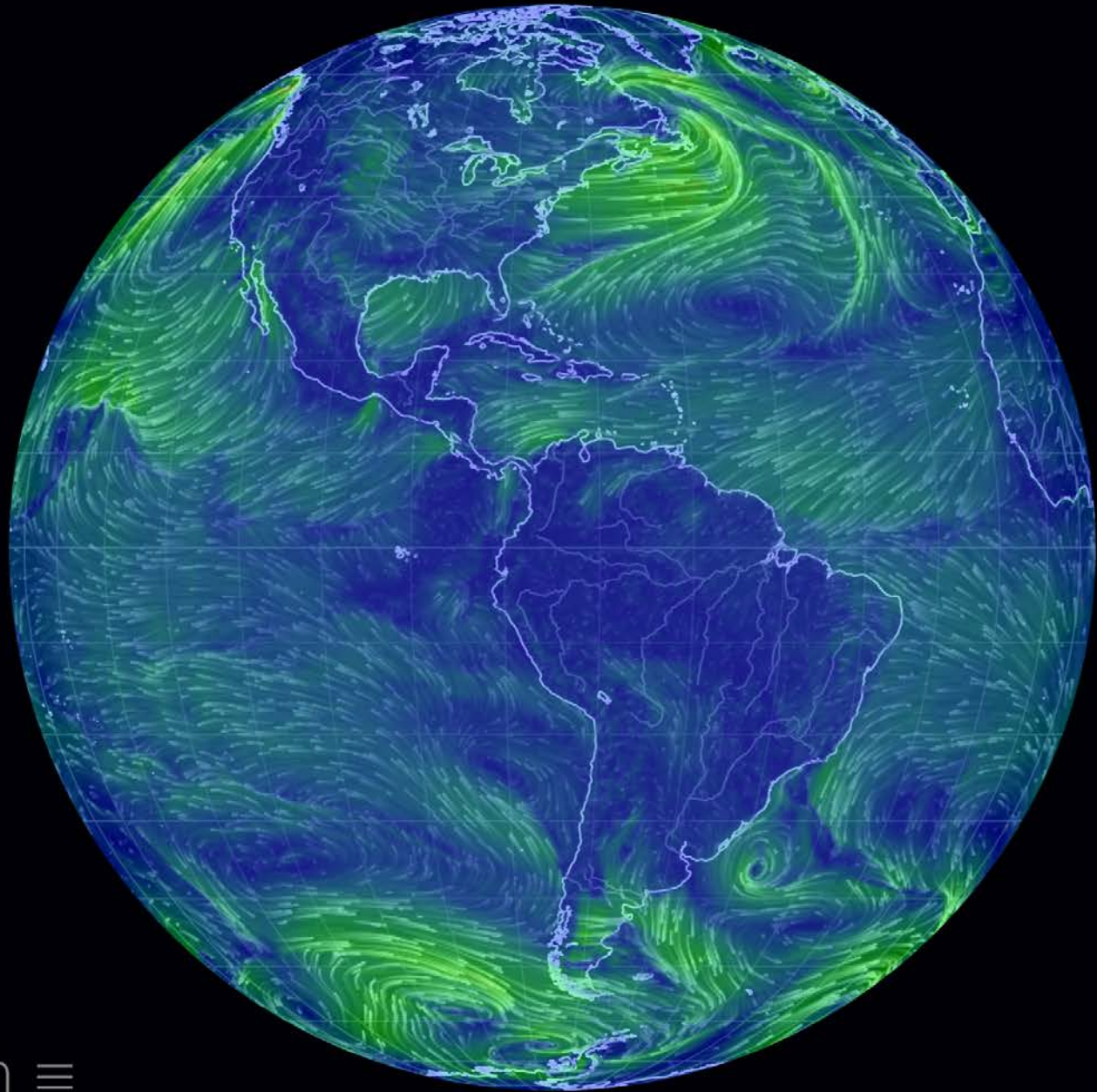
VII.10  
History of Science Fiction, by Ward Shelley

BROOKLYN, NY 2011  
Courtesy of Ward Shelley Studios

Ward Shelley is an artist identified with the Williamsburg scene in Brooklyn, New York. This map plots the science fiction literary genre from its nascent roots in the 18th century, emerging out of the data, here the narrative structure precedes and organizes the data. The map's structure is like trace roots to pre-historical sources and whose body of work, Romanticism, which birthed gothic fiction, source not only of Sci-Fi, but also of critical theory. The map progressed through a number of distinct periods, which are charted, citing hundreds of authors and works.

PLACES & SPACES  
MAPPING ARTISTS

Visit [scimaps.org](http://scimaps.org) and check out all our maps in stunning detail!



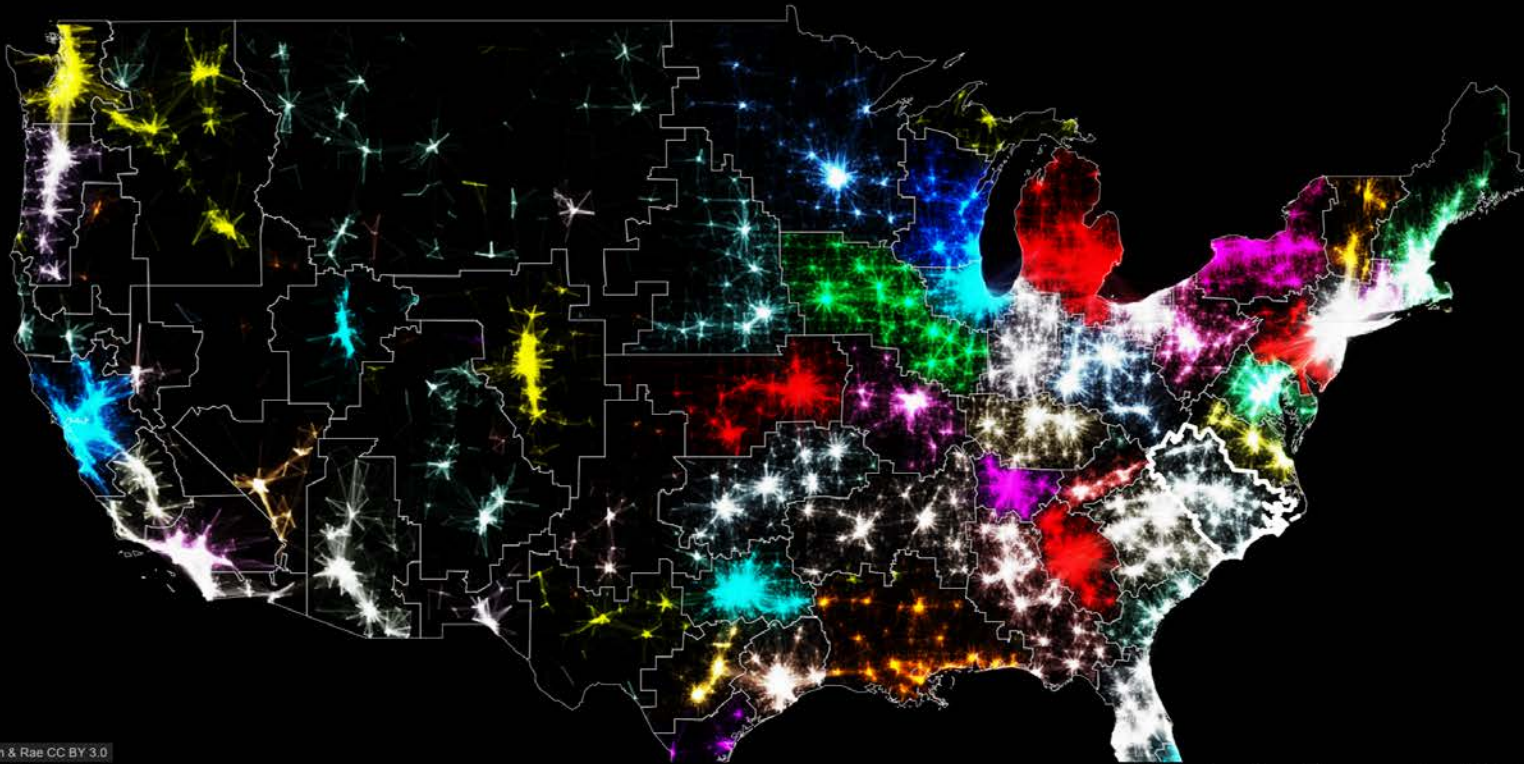
earth ≡

*Earth* – Cameron Beccario



## THE MEGAREGIONS OF THE US

Explore the new geography of commuter connections in the US.  
Tap to identify regions. Tap and hold to see a single location's commuted.



Leaflet | Nelson & Rae CC BY 3.0

This is the Roanoke (Raleigh) megaregion.



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## Visual Analytics - IVMOOC

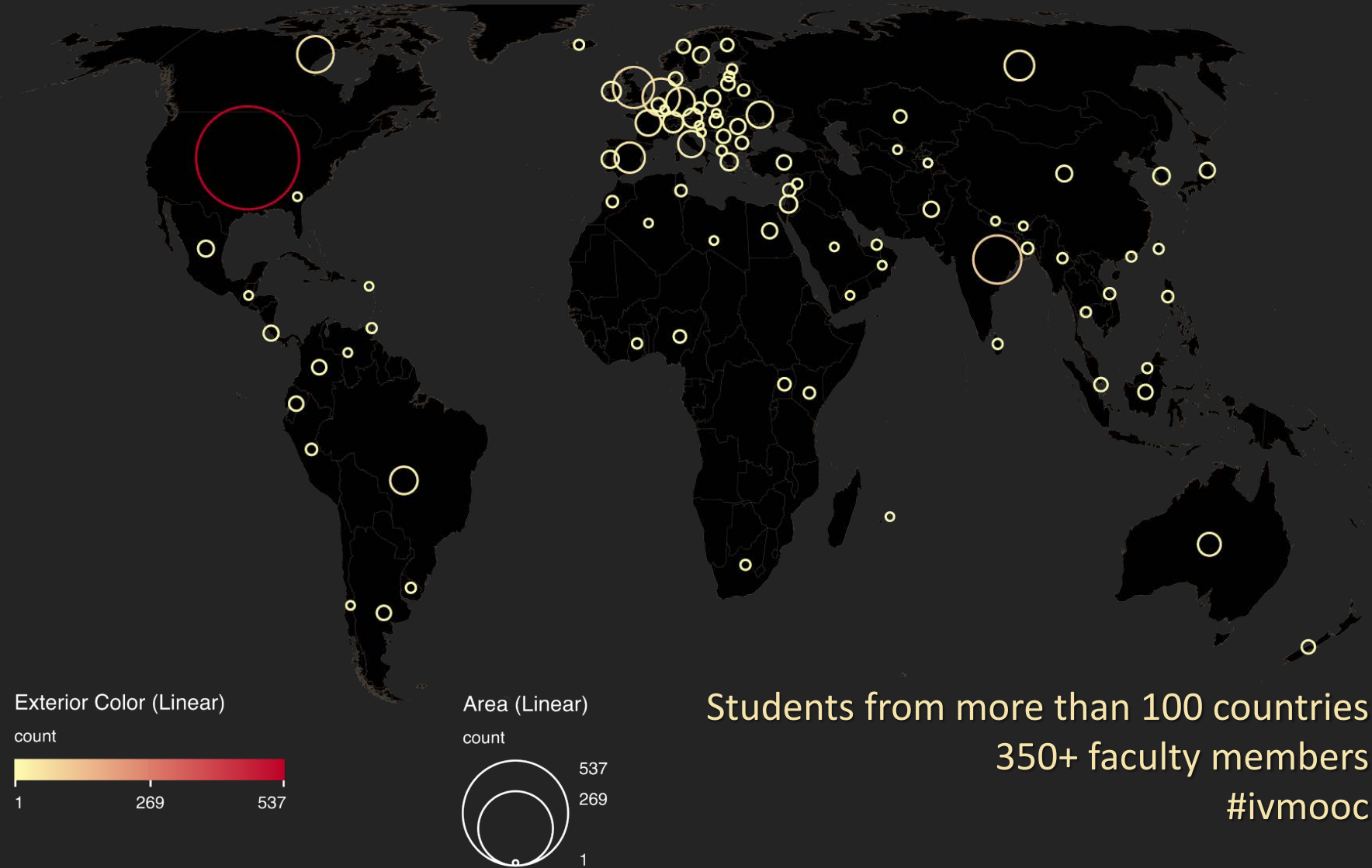




Register for free: <http://ivmooc.cns.iu.edu>

# The Information Visualization MOOC

[ivmooc.cns.iu.edu](http://ivmooc.cns.iu.edu)



# Data Visualization Literacy

*Data visualization literacy* (ability to read, make, and explain data visualizations) requires

- *literacy* (ability to read and write text, e.g., in titles, axis labels, legend),
- *visual literacy* (ability to find, interpret, evaluate, use, and create images and visual media), and
- *data literacy* (ability to read, create, and communicate data).

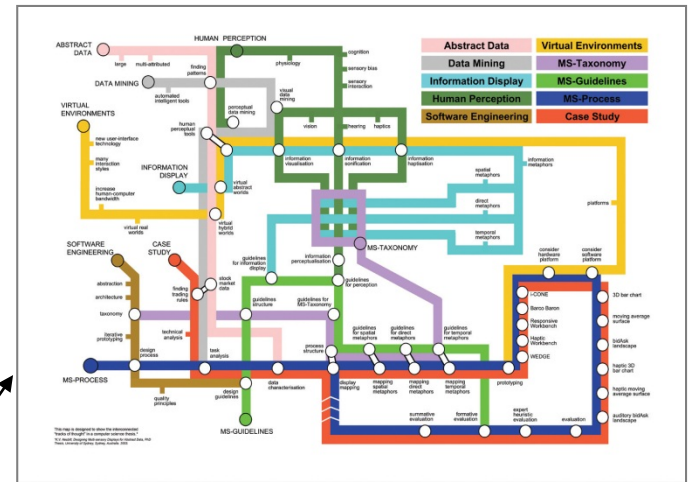
Being able to “read and write” data visualizations is becoming as important as being able to read and write text. Understanding, measuring, and improving data and visualization literacy is important for understanding STEAM developments and to strategically approach global issues.

# Different Question Types



Terabytes of data

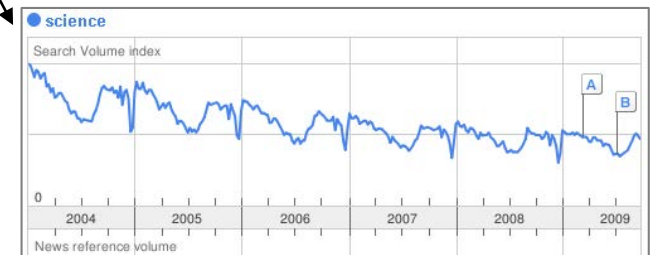
Descriptive & Predictive Models



Find your way



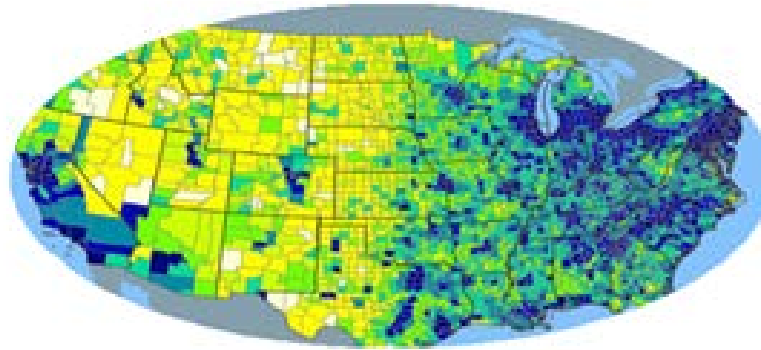
Find collaborators, friends



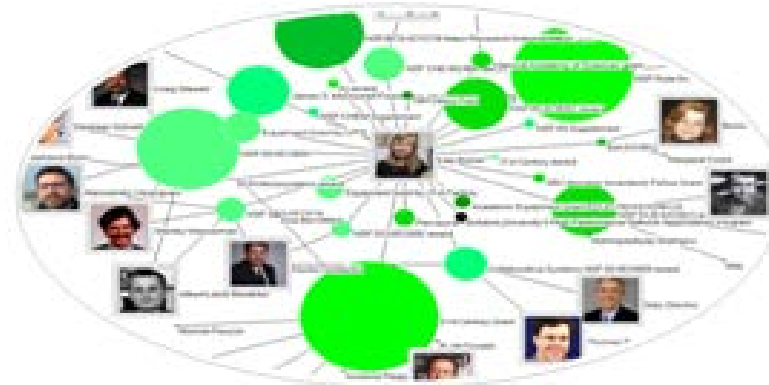
Identify trends

# Different Levels of Abstraction/Analysis

Macro/Global  
Population Level



Meso/Local  
Group Level



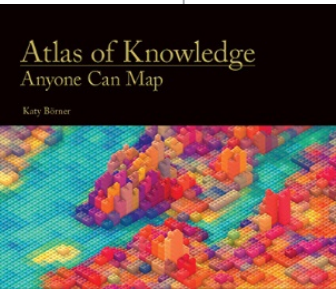
Micro  
Individual Level



# Tasks

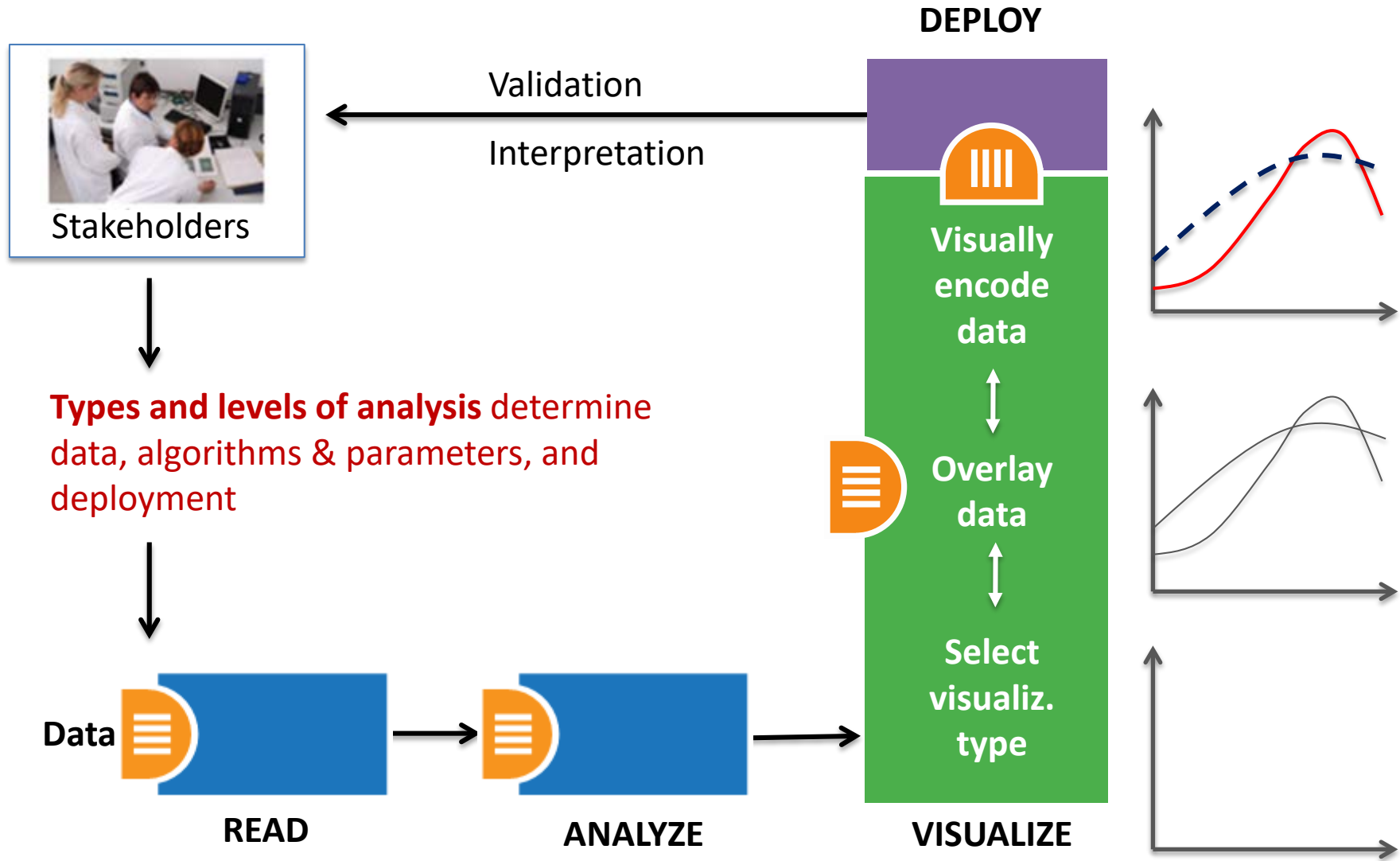
## LEVELS

	<b>MICRO: Individual Level</b> about 1–1,000 records page 6	<b>MESO: Local Level</b> about 1,001–100,000 records page 8	<b>MACRO: Global Level</b> more than 100,000 records page 10
<b>TYPES</b>			
<b>Statistical Analysis</b> page 44	 Knowledge Cartography page 135	 Productivity of Russian life sciences research teams page 105	 Science and Society in Equilibrium Number of scientists versus population and R&D costs versus GNP. page 103
<b>WHEN: Temporal Analysis</b> page 48	 Visualizing decision-making processes page 95	 Key events in the development of the video tape recorder page 85	 Increased travel and communication speeds page 83
<b>WHERE: Geospatial Analysis</b> page 52	 Cell phone usage in Milan, Italy page 109	 Victorian poetry in Europe page 137	 Ecological footprint of countries page 99
<b>WHAT: Topical Analysis</b> page 56	 Evolving patent holdings of Apple Computer, Inc. and Jerome Lemelson page 89	 Evolving journal networks in nanotechnology page 139	 Product space showing co-export patterns of countries page 93
<b>WITH WHOM: Network Analysis</b> page 60	 World Finance Corporation network page 87	 Electronic and new media art networks page 133	 World-wide scholarly collaboration networks page 157

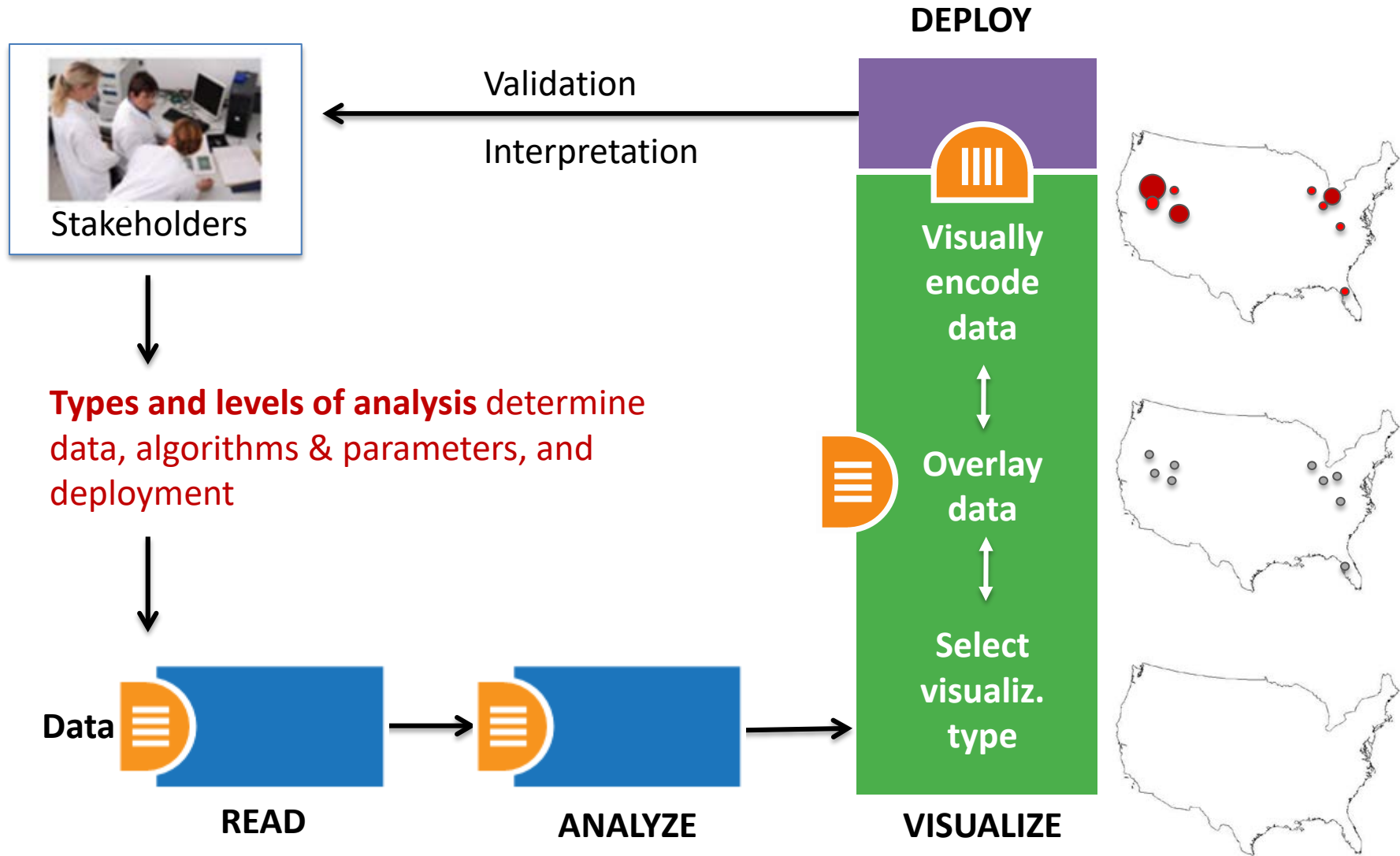


See *Atlas of Science: Anyone Can Map*, page 5

# Needs-Driven Workflow Design



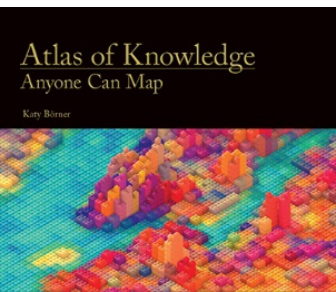
# Needs-Driven Workflow Design





# Visualization Framework

Insight Need Types page 26	Data Scale Types page 28	Visualization Types page 30	Graphic Symbol Types page 32	Graphic Variable Types page 34	Interaction Types page 26
<ul style="list-style-type: none"> <li>• categorize/cluster</li> <li>• order/rank/sort</li> <li>• distributions (also outliers, gaps)</li> <li>• comparisons</li> <li>• trends (process and time)</li> <li>• geospatial</li> <li>• compositions (also of text)</li> <li>• correlations/relationships</li> </ul>	<ul style="list-style-type: none"> <li>• nominal</li> <li>• ordinal</li> <li>• interval</li> <li>• ratio</li> </ul>	<ul style="list-style-type: none"> <li>• table</li> <li>• chart</li> <li>• graph</li> <li>• map</li> <li>• network layout</li> </ul>	<ul style="list-style-type: none"> <li>• geometric symbols               <ul style="list-style-type: none"> <li>point</li> <li>line</li> <li>area</li> <li>surface</li> <li>volume</li> </ul> </li> <li>• linguistic symbols               <ul style="list-style-type: none"> <li>text</li> <li>numerals</li> <li>punctuation marks</li> </ul> </li> <li>• pictorial symbols               <ul style="list-style-type: none"> <li>images</li> <li>icons</li> <li>statistical glyphs</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• spatial               <ul style="list-style-type: none"> <li>position</li> </ul> </li> <li>• retinal               <ul style="list-style-type: none"> <li>form</li> <li>color</li> <li>optics</li> <li>motion</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• overview</li> <li>• zoom</li> <li>• search and locate</li> <li>• filter</li> <li>• details-on-demand</li> <li>• history</li> <li>• extract</li> <li>• link and brush</li> <li>• projection</li> <li>• distortion</li> </ul>



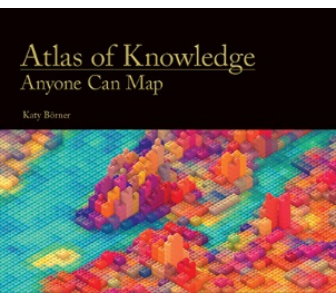
See *Atlas of Science: Anyone Can Map*, page 24

# Visualization Framework

Basic Task Types								
Bertin, 1967	Wehrend & Lewis, 1996	Few, 2004	Yau, 2011	Rendgen & Wiedemann, 2012	Frankel, 2012	Tool: Many Eyes	Tool: Chart Chooser	Börner, 2014
selection	categorize			category				categorize/ cluster
order	rank	ranking					table	order/rank/ sort
	distribution	distribution					distribution	distributions (also outliers, gaps)
	compare	nominal comparison & deviation	differences		compare and contrast	compare data values	comparison	comparisons
		time series	patterns over time	time	process and time	track rises and falls over time	trend	trends (process and time)
		geospatial	spatial relations	location		generate maps		geospatial
quantity		part-to- whole	proportions		form and structure	see parts of whole, analyze text	composition	compositions (also of text)
association	correlate	correlation	relationships	hierarchy		relations between data points	relationship	correlations/ relationships

# Visualization Framework

Insight Need Types page 26	Data Scale Types page 28	Visualization Types page 30	Graphic Symbol Types page 32	Graphic Variable Types page 34	Interaction Types page 26
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See *Atlas of Science: Anyone Can Map*, page 24

# Graphic Variable Types Versus Graphic Symbol Types

			Geometric Symbols					
			Point		Line		Area	
Spatial	x	quantitative						
	y	quantitative						
	z	quantitative						
Retinal	Form	Size	quantitative	NA (Not Applicable)				
		Shape	qualitative	NA				
		Rotation	quantitative	NA				
		Curvature	quantitative	NA				
		Angle	quantitative	NA				
		Closure	quantitative	NA				
	Color	Value	quantitative					
Hue		qualitative						
Saturation		quantitative						

# Graphic Variable Types Versus Graphic Symbol Types

			Geometric Symbols			Linguistic Symbols Text, Numerals, Punctuation Marks		Pictorial Symbols Images, Icons, Statistical Glyphs	
Spatial	x	quantitative							
	y	quantitative							
	z	quantitative							
Form	Size	quantitative	NA (Not Applicable)						
	Shape	qualitative	NA						
	Rotation	quantitative	NA						
	Curvature	quantitative	NA						
	Angle	quantitative	NA						
	Closure	quantitative	NA						
	Value	quantitative							
Color	Hue	qualitative							
	Saturation	quantitative							

			Geometric Symbols			Linguistic Symbols Text, Numerals, Punctuation Marks		Pictorial Symbols Images, Icons, Statistical Glyphs	
Texture	Spacing	quantitative							
	Granularity	quantitative							
	Pattern	qualitative							
	Orientation	quantitative	NA						
	Gradient	quantitative							
	Blur	quantitative							
	Transparency	quantitative							
Optics	Shading	quantitative							
	Stereoscopic Depth	quantitative	Point in foreground -- background	Line in foreground -- background	Area in foreground -- background	Surface in foreground -- background	Volume in foreground -- background	Text in foreground -- background	Icons in foreground -- background
	Speed	quantitative							
Motion	Velocity	quantitative							
	Rhythm	quantitative	Blinking point slow -- fast	Blinking line slow -- fast	Blinking area slow -- fast	Blinking surface slow -- fast	Blinking volume slow -- fast	Blinking text slow -- fast	Blinking icons slow -- fast

# Course Schedule

## Part 1: Theory and Hands-On

- **Session 1** – Workflow Design and Visualization Framework
- **Session 2** – “When:” Temporal Data
- **Session 3** – “Where:” Geospatial Data
- **Session 4** – “What:” Topical Data

## Mid-Term

- **Session 5** – “With Whom:” Trees
- **Session 6** – “With Whom:” Networks
- **Session 7** – Dynamic Visualizations and Deployment

## Final Exam

## Part 2: Students work in teams on client projects.

Final grade is based on Homework and Quizzes (**10%**), Midterm (**20%**), Final (**30%**), Client Project (**30%**), and Class Participation (**10%**).



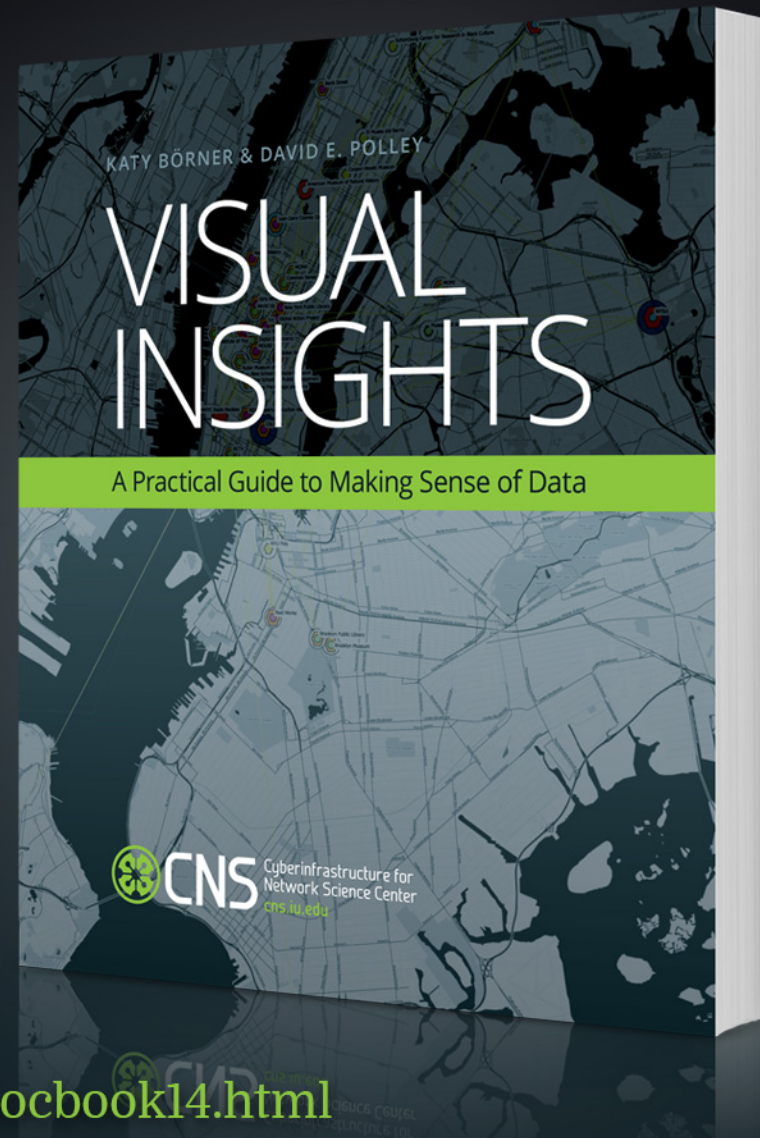
# The IVMOOC Companion Textbook

This textbook offers a gentle introduction to the design of insightful visualizations. It seamlessly blends theory and practice, giving readers both the theoretical foundation and the practical skills necessary to render data into insights.

The book accompanies the Information Visualization MOOC that attracted students, scholars, and practitioners from many fields of science and more than 100 different countries.

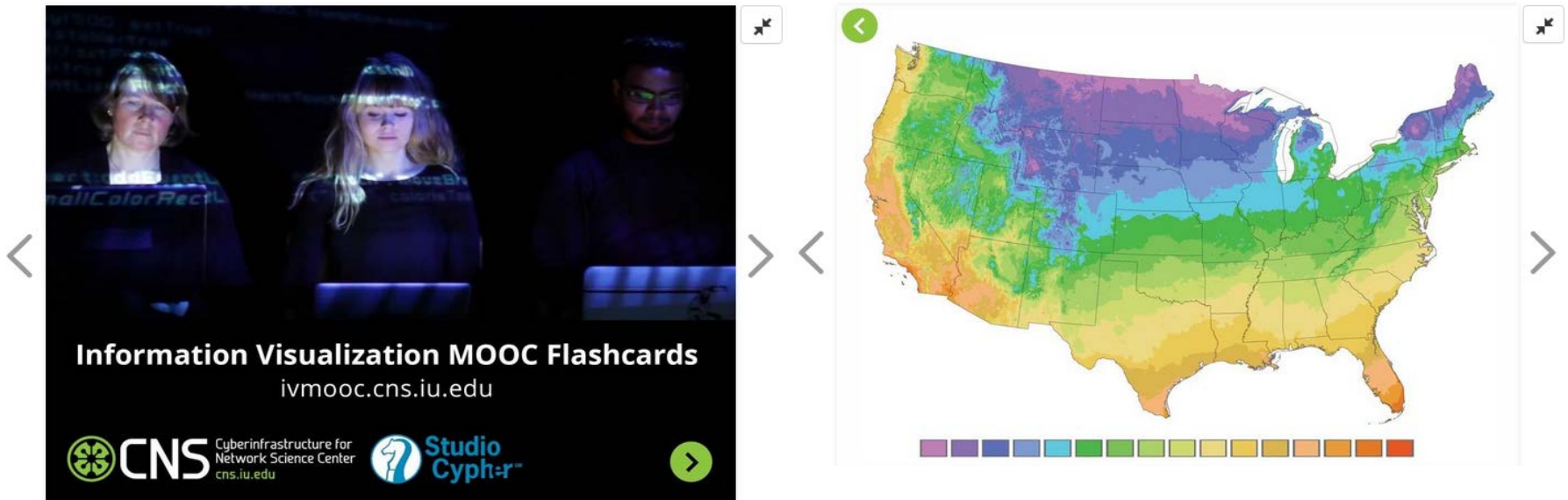
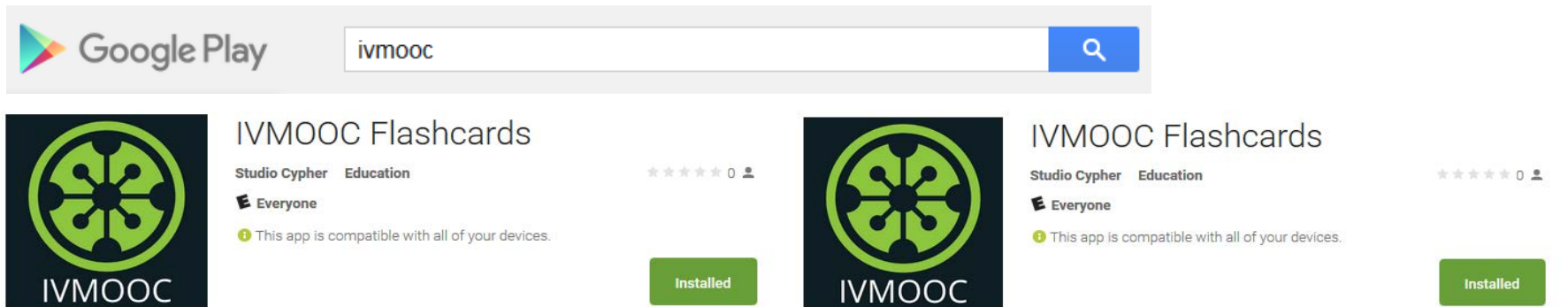
<http://ivmooc.cns.iu.edu>

[cns.iu.edu/ivmoocbook14.html](http://cns.iu.edu/ivmoocbook14.html)



# IVMOOC App

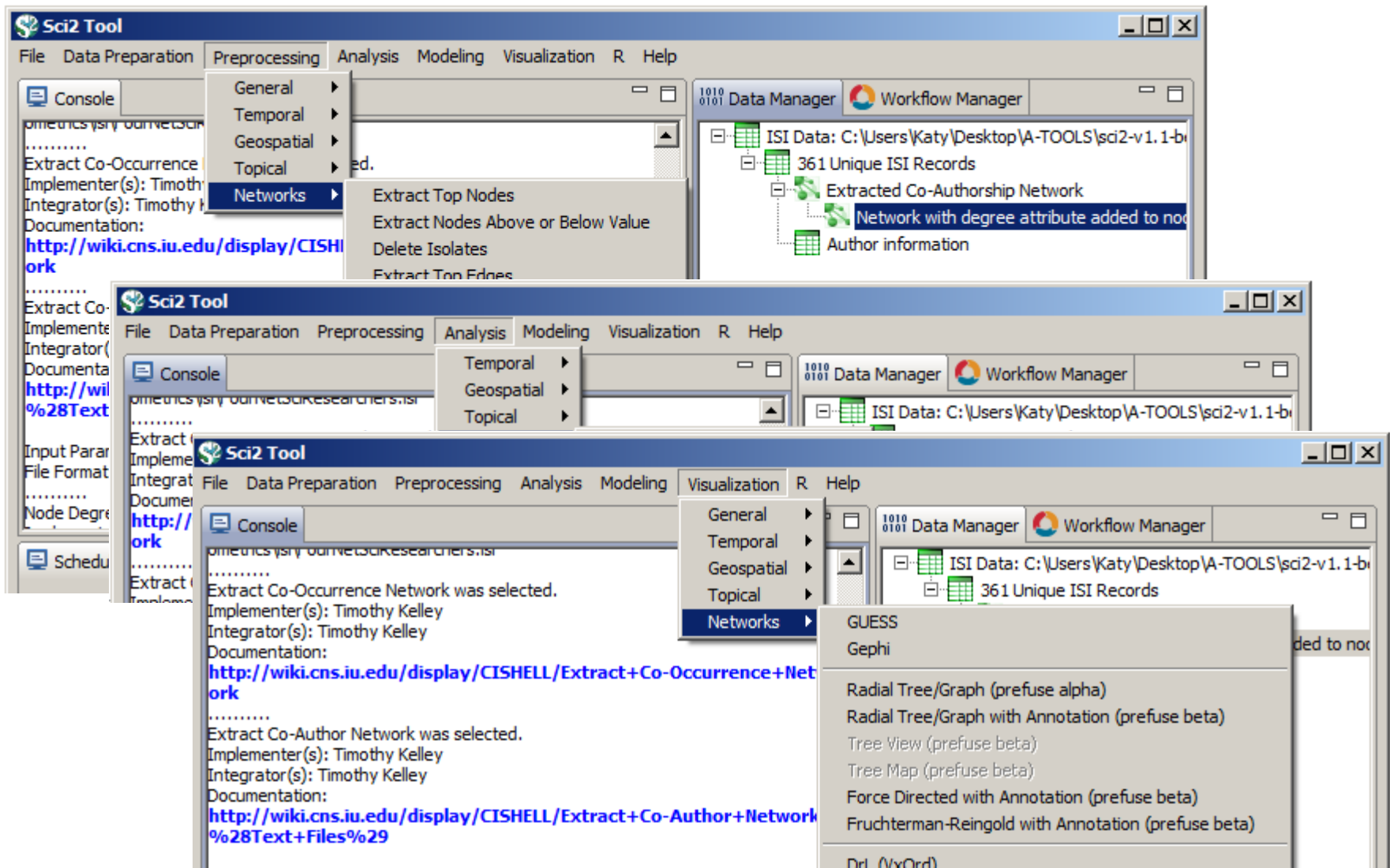
The “IVMOOC Flashcards” app can be downloaded from Google Play and Apple iOS stores.





# Sci2 Tool Interface Components Implement Vis Framework

Download tool for free at <http://sci2.cns.iu.edu>



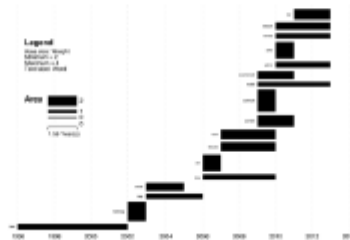
# Load **One** File and Run **Many** Analyses and Visualizations

Times Cited	Publication Year	City of Publisher	Country	Journal Title (Full)	Title	Subject Category	Authors
12	2011	NEW YORK	USA	COMMUNICATIONS OF THE ACM	Plug-and-Play Microscopes	Computer Science	Borner, K
18	2010	MALDEN	USA	CTS-CLINICAL AND TRANSLATIONAL SCIENCE	Advancing the Science of Team Science	Research & Experimental Medicine	Falk-Krzesinski, HJ Borner, K Contractor, N Fiore, SM Hall, KL Keyton, J Spring, B Stokols, D Trochim, W Uzzi, B
13	2010	WASHINGTON	USA	SCIENCE TRANSLATIONAL MEDICINE	A Multi-Level Systems Perspective for the Science of Team Science	Cell Biology   Research & Experimental Medicine	Borner, K Contractor, N Falk-Krzesinski, HJ Fiore, SM Hall, KL Keyton, J Spring, B Stokols, D Trochim, W Uzzi, B

Statistical Analysis—p. 44

Location	Count	# Citations
Netherlands	13	292
United States	9	318
Germany	11	36
United Kingdom	1	2

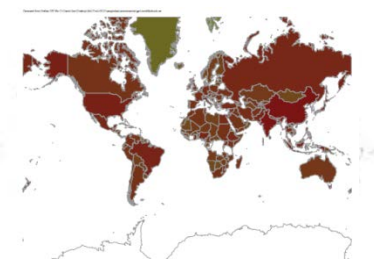
Temporal Burst Analysis—p. 48



Geospatial Analysis—p. 52



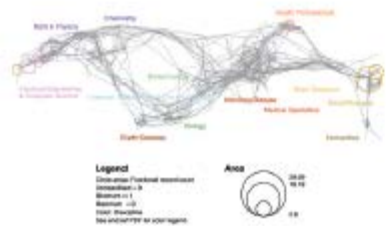
Geospatial Analysis—p. 52



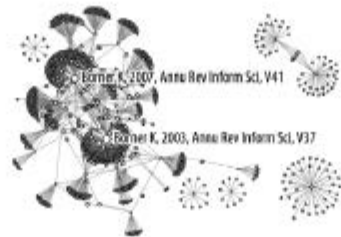
# Load **One** File and Run **Many** Analyses and Visualizations

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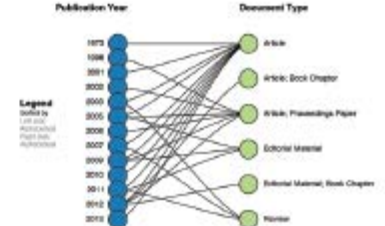
Topical Analysis—p. 56



Paper Citation Network—p. 60



Bi-Modal Network—p. 60



Co-author and many other bi-modal networks.

Santa Fe Institute



## Learning Analytics



# Learning Analytics

**Empowering Teachers:** How to make sense of the activities of thousands of students? How to guide them?

**Empowering Students:** How to navigate learning materials and develop successful learning collaborations across disciplines and time zones?

**Empowering Researchers:** How do people learn? What pedagogy works (in a MOOC) and when?

**Empowering MOOC Platform Designers:** What technology helps and what hurts?



# Visualizing IVMOOC Data

Data was collected from different sources:

- 1,901 students registered via GCB (1215 male/557 female)
- 52,557 slide downloads from our server
- 18,893 video views via YouTube
- 193 accounts made 730 tweets
- 134 students took 183 exams in GCB
- 674 remarks on 215 different forum threads in Drupal
- 64 students submitted projects via Drupal



# Learning Analytics

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# Visualizing IVMOOC Data

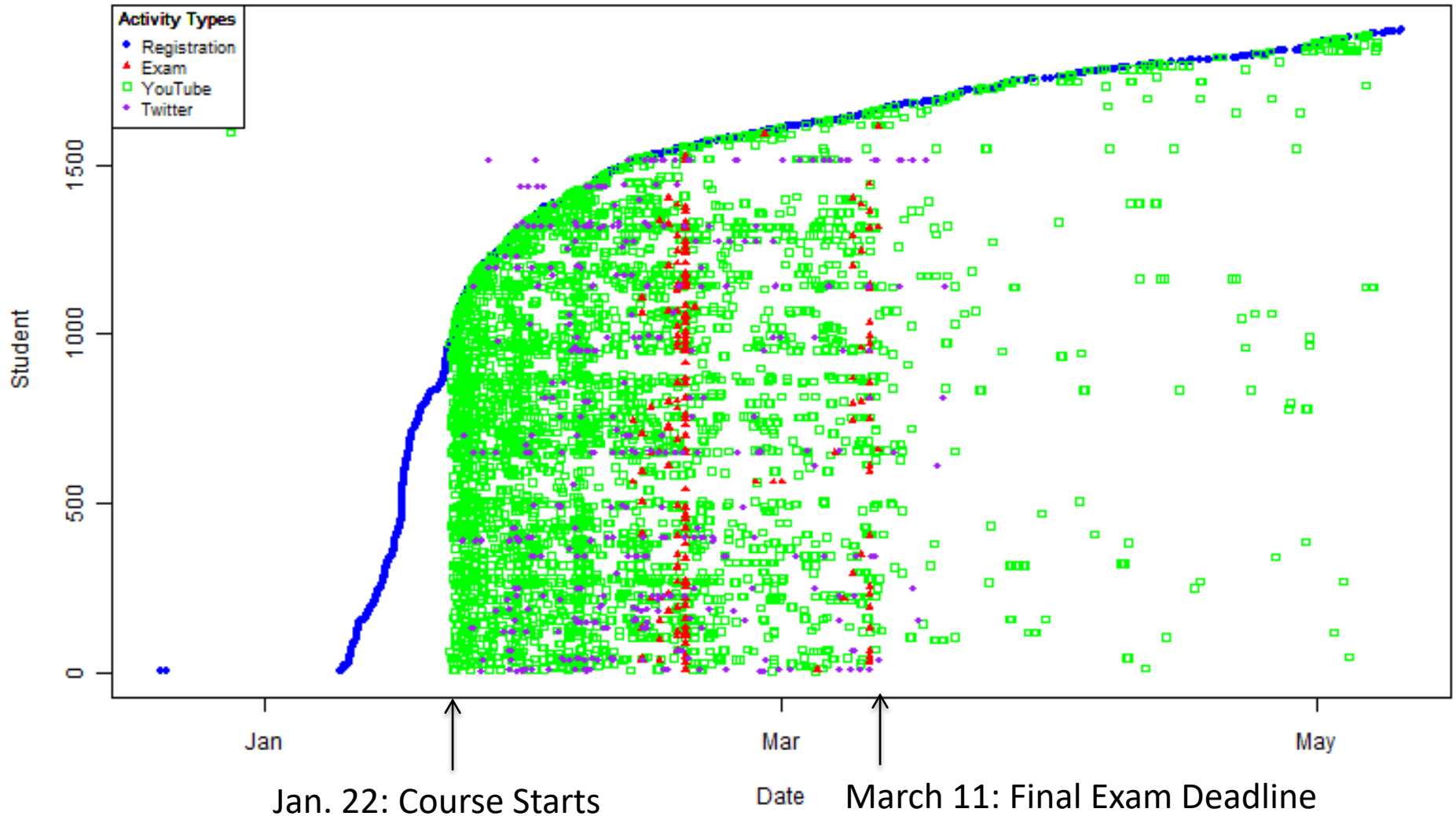
Data was collected from different sources:

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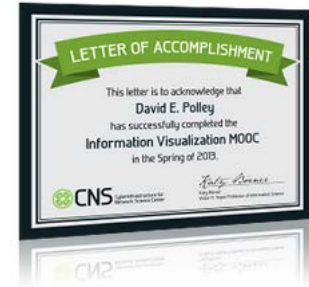




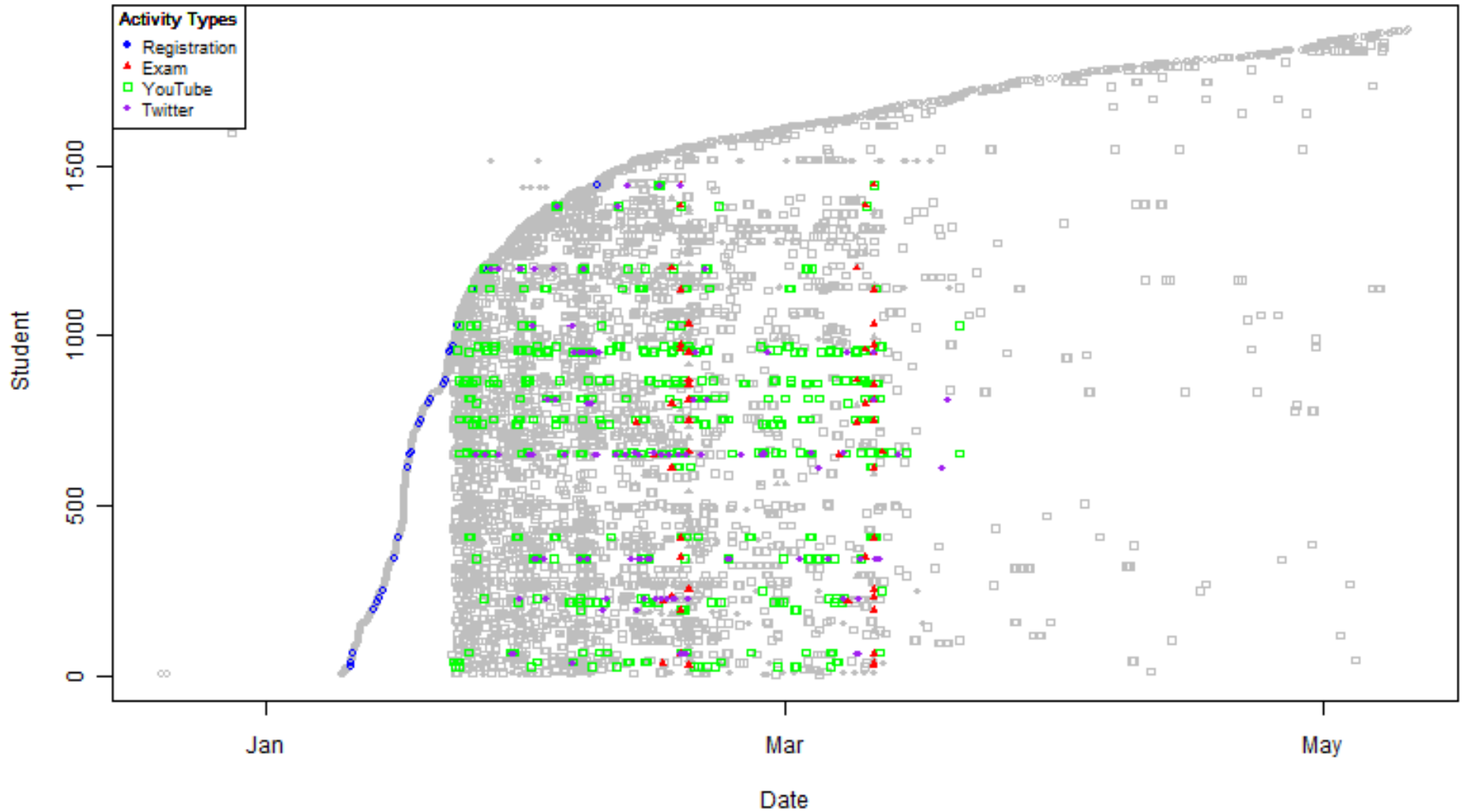
# Student Registration and Activity



# Student Registration and Activity



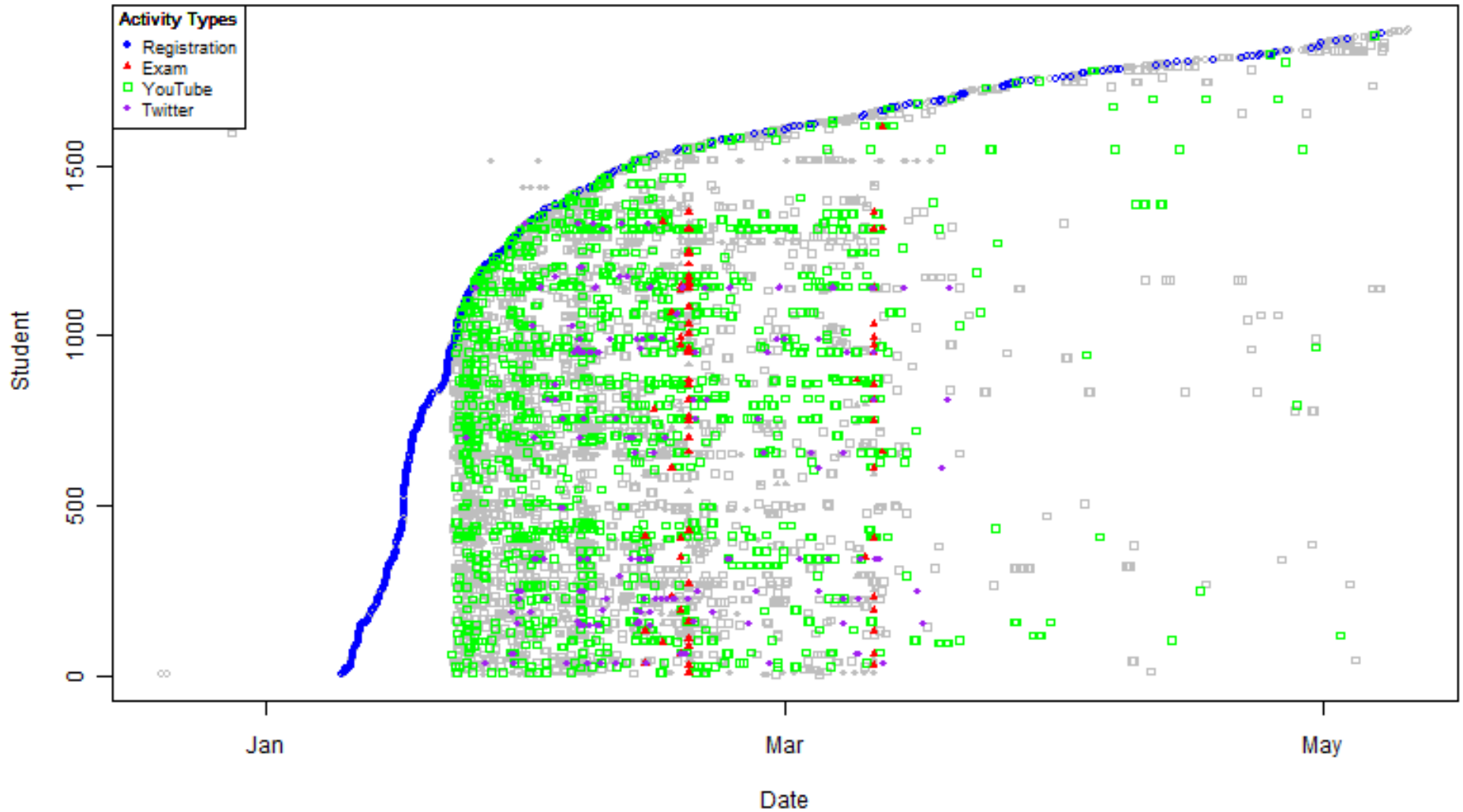
IVMOOC Student Activity (Achievement Badge)



# Student Registration and Activity

1215 male students  
557 female students

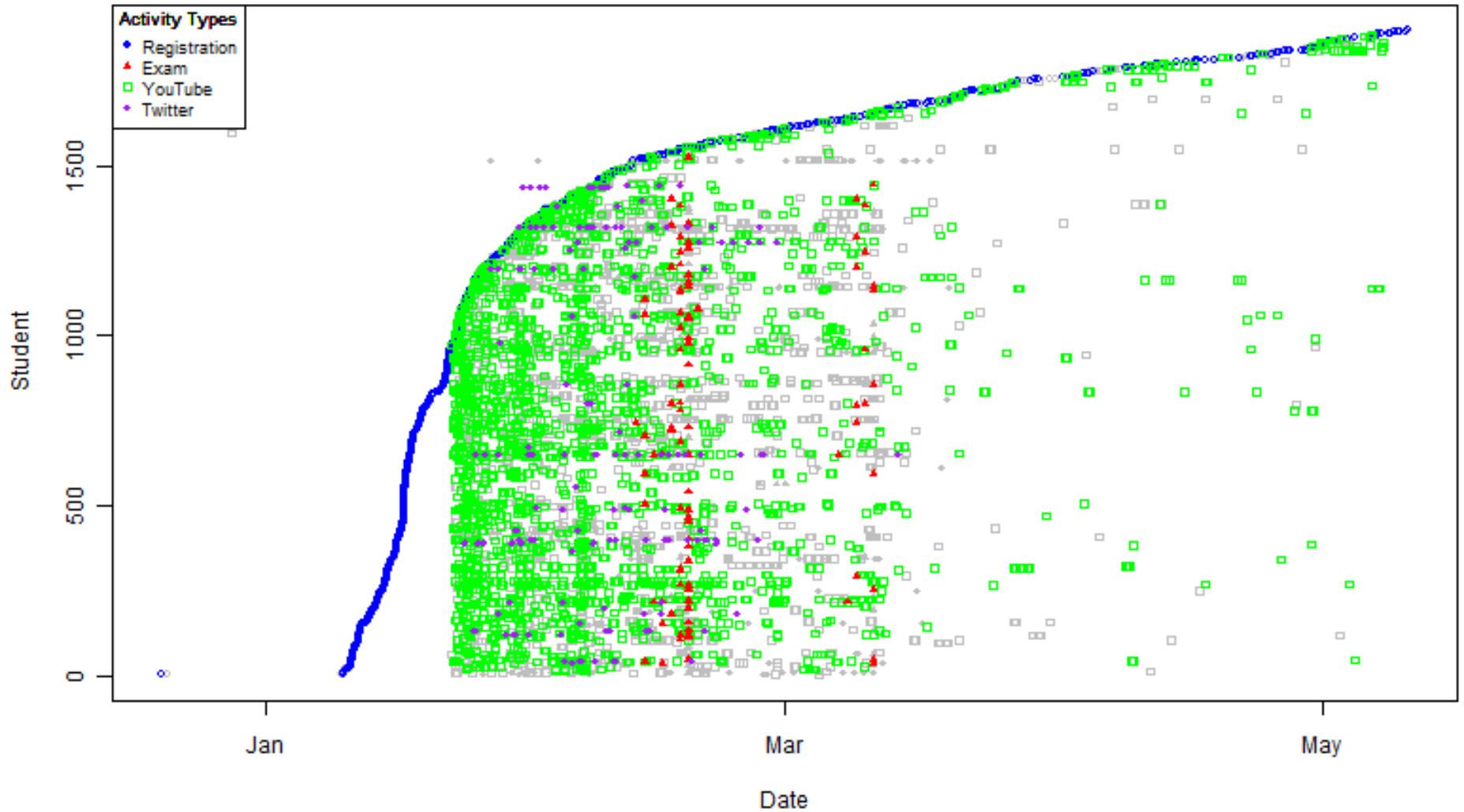
## Female IVMOOC Student Activity



# Student Registration and Activity

1215 male students  
557 female students

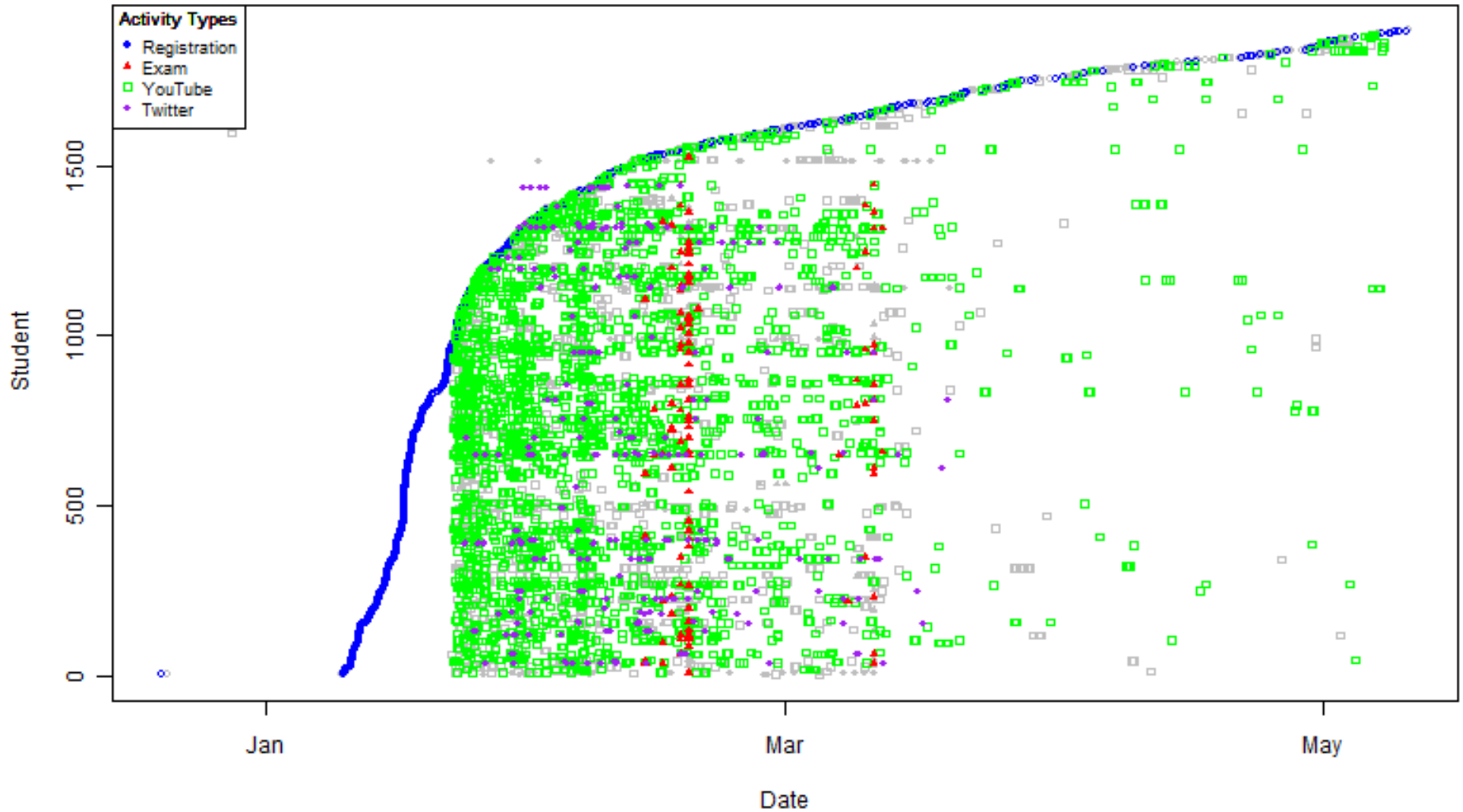
## Male IVMOOC Student Activity





# Student Registration and Activity

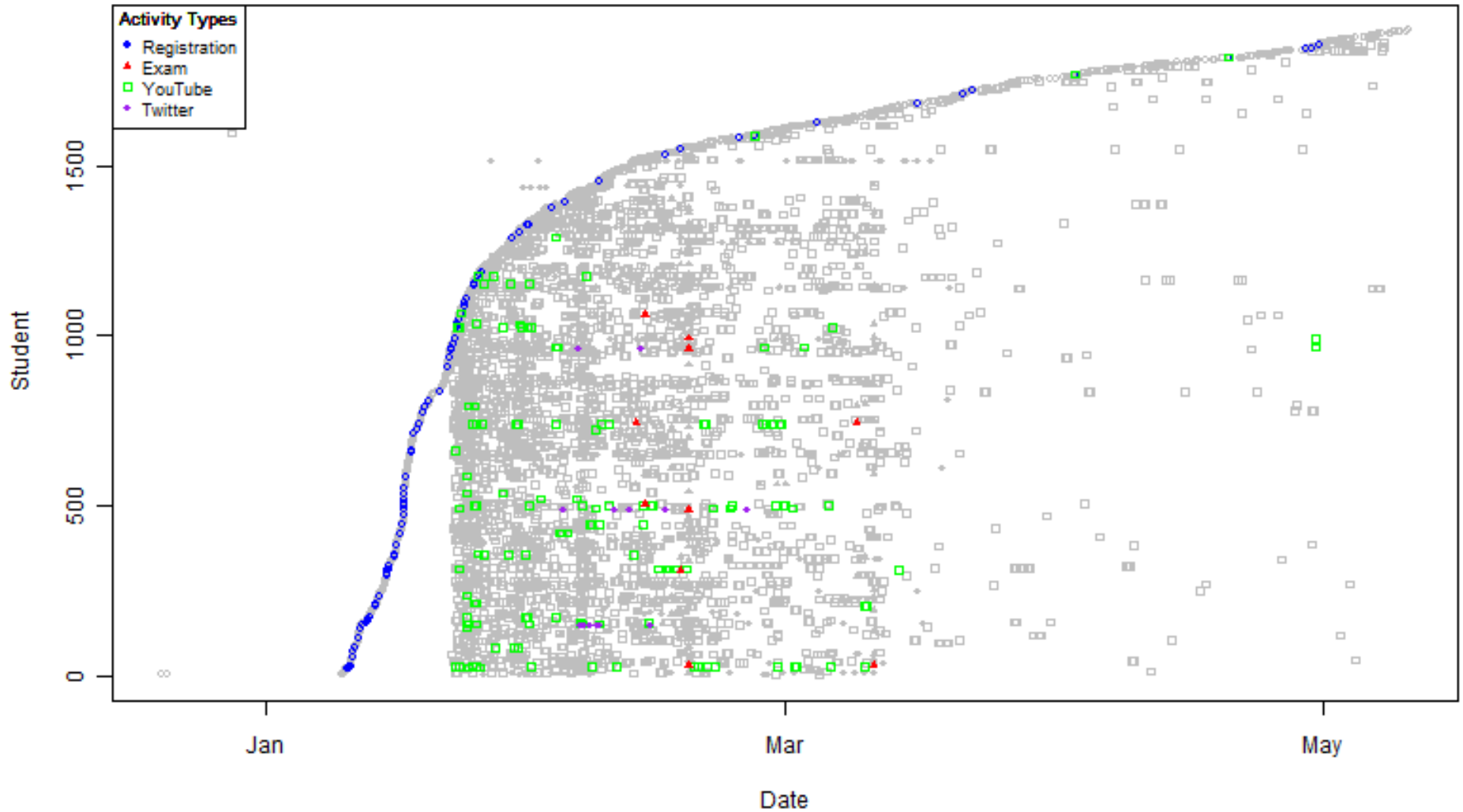
## Novice IVMOOC Student Activity





# Student Registration and Activity

## Expert IVMOOC Student Activity





# Student Client Projects: All Interactions



# Student Engagement and Performance

## Learning Analytics

IVMOOC 2015 Student Group Engagement and Scores

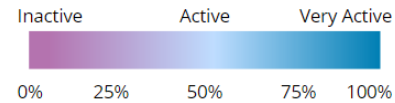
	Pre-Course	Week 1	Week 2	Week 3	Week 4	Midterm	Week 5	Week 6	Week 7	Week 8	Week 9	Final	Curr. Score
IVMOOC	26.05%	38.32%	31.32%	29.96%	27.1%	28.34%	31.07%	24.28%	16.86%	18.23%	13.08%	13.41%	20.87%
Z637-29374	33.01%	52.91%	49.89%	59.22%	50.89%	82.56%	65.04%	49.99%	39.59%	61.63%	54.91%	82.25%	82.4%
Z637-32593	25.08%	54.54%	43.58%	50.67%	53.63%	77.67%	65.7%	59.48%	52.19%	65.71%	47.27%	72.59%	75.13%
Z637-33781	29.33%	55.38%	49.26%	62.18%	77.47%	85%	87.4%	69.8%	55.56%	57.6%	45.69%	70.89%	77.94%

IVMOOC 2015 Student Group Engagement for Midterm

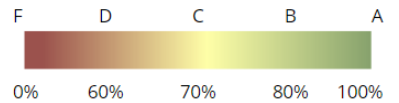
	Midterm	Final	Curr. Score	Overall Engagement
Student 198	100%	85.33%	92.67%	30.34%
Student 210	100%	84%	92%	33.91%
Student 242	97.14%	98.67%	97.9%	55.89%
Student 265	95.71%	92%	93.86%	82.64%
Student 216	95.71%	24%	59.86%	34.92%
Student 257	94.29%	98.67%	96.48%	68.25%
Student 264	94.29%	89.33%	91.81%	80.47%
Student 262	94.29%	85.33%	89.81%	79.65%

### Legends

#### Engagement



#### Score



### Description

The heat map visualization is a representation of student engagement (magenta to blue color scale) and performance (red to green color scale) throughout a course. The visualization has two levels. The top level provides an overview of engagement and performance for groups of students, while the bottom level provides a detailed break out of student engagement statistics for individuals with an identified group.

Custom interactive visualizations of IVMOOC student engagement and performance data, explore functionality online at <http://goo.gl/TYixCn>



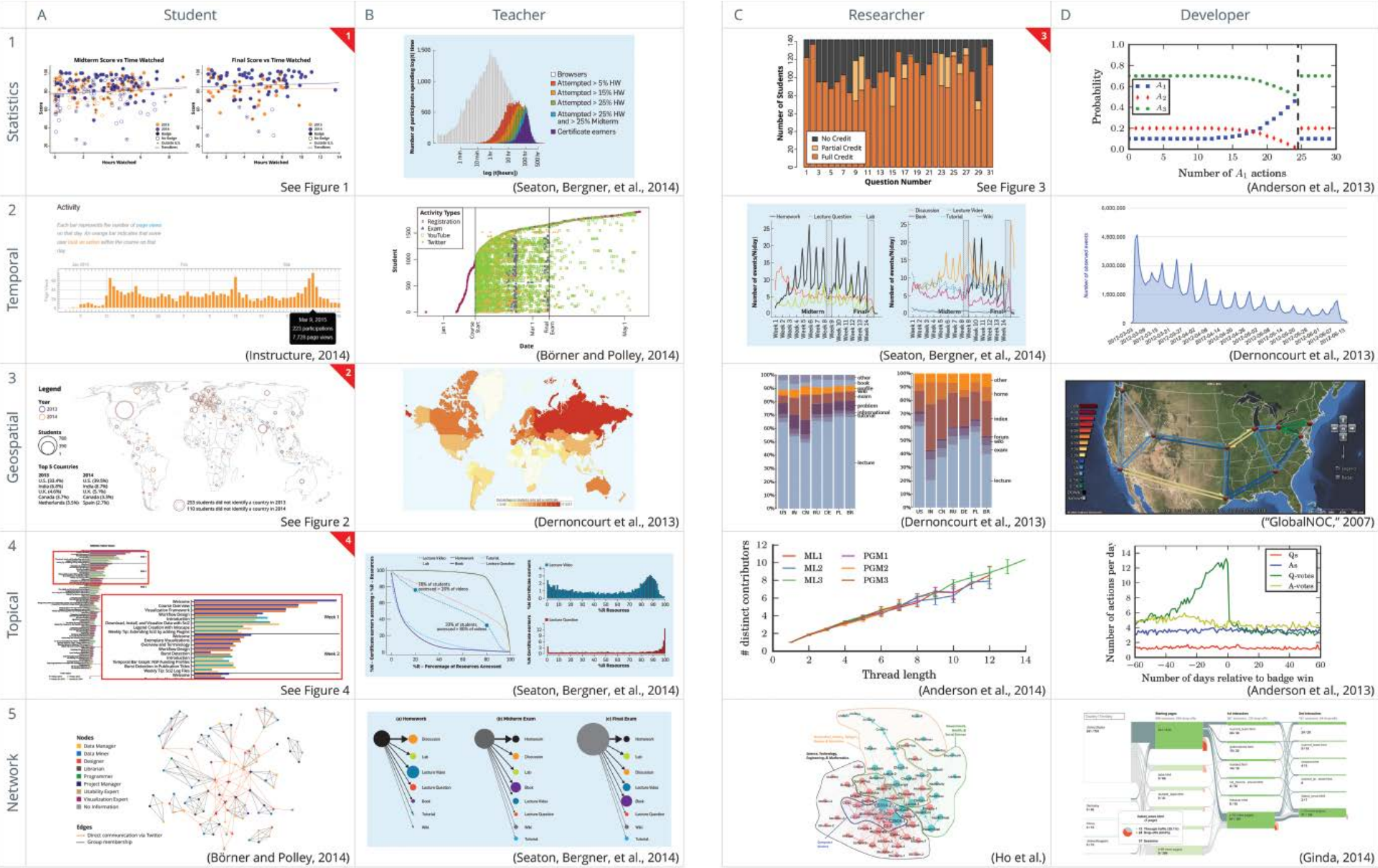


Figure 1: Analysis types vs. user needs.

Emmons, Light, and Börner. "[MOOC Visual Analytics: Empowering Teachers, Students, Researchers, and Developers of Massively Open Online Courses](#)". *Journal of the Association for Information Science and Technology* (in press).

# Next Generation IVMOOC

**Instructor:** Victor H. Yngve Distinguished Professor Katy Börner & CNS Team, ISE, SICE, IUB

**Duration:** 6 weeks x 5 hours = 30 hours (3 CEUs)

**Format:** Online | Theory and Hands-on Instruction, Concept Questions, Graded Assignments, Case Studies, Discussions

**Start:** Sept 15, 2018

## Covers:

Temporal, geospatial, topical (linguistic), network analyses and 60+ visualization types

**Tools:** Tableau, Gephi, BI,

**Industry case studies** such as

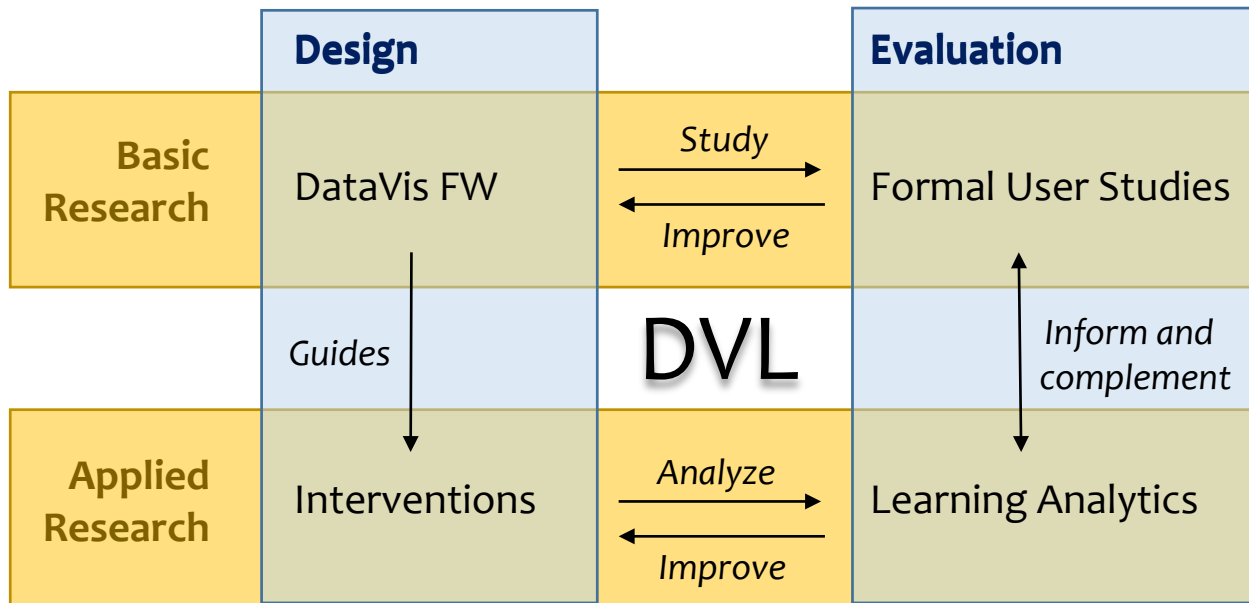
- Acting on customer complaints data.
- Improving communication/traffic flows.
- Understanding web page usage.
- Visualizing online shopping behavior.
- Optimizing supply chains.
- Reducing customer/supplier churn.
- Monitoring emerging R&D areas.
- Workforce development planning.

The screenshot displays the IVC MOOC website. At the top, the CNS logo is visible. The main heading is "IVC MOOC Data Visualization Essentials". Below this, there are two short stories: "Here's the story of a lovely lady. Who was bringing up three very lovely girls. All of them had hair of gold. Like their mother. The youngest one in suits." and "Here's the story of a man named Brady. Who was busy as three boys of his own. They were four men, living all together, yet they were all alone." A "Register" button is present. The main content area features a grid of six visualization examples, each labeled "Visualizing Framework & Workflow Design". The examples include: 1) A circular sunburst chart with orange and yellow segments. 2) A network graph with dark nodes and edges. 3) A map with red circular markers of varying sizes. 4) A world map with dark nodes and connecting lines. 5) A network graph with nodes of various colors (blue, green, orange, red) and a legend. 6) A complex network graph with red and blue nodes and edges. Below the grid is a "Course Books" section with four book covers: "Visual Insights", "Atlas of Knowledge", "Atlas of Knowledge", and "Atlas of Science". Each book has an "Order" button. The footer contains the text "© 2018 CNS Center of Informatics & Statistics" and "Privacy | Terms of Service".

# Next Generation IVMOOC

Systematic study of how different student cohorts learn best—using Mechanical Turk formal user studies and extensive learning analytics.

Optimization of **Data Visualization Framework** and **Learning Modules**.



# Next Generation IVMOOC

Systematic study of how different student cohorts learn best—using **Mechanical Turk formal user studies**, e.g., to optimize horizontal transfer:

*Table*

*Columns by rows*

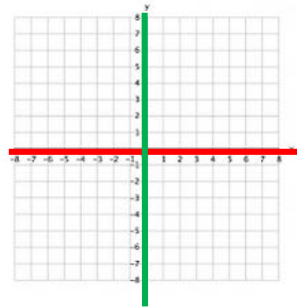
column row

<i>x</i>	<i>y</i>
0	3
2	11
4	19
6	27
8	35

cell

*Graph*

*x-y coordinates*  
*linear/log scale*



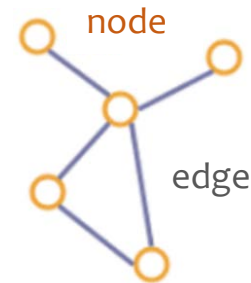
*Map*

*Latitude/*  
*longitude*



*Network*

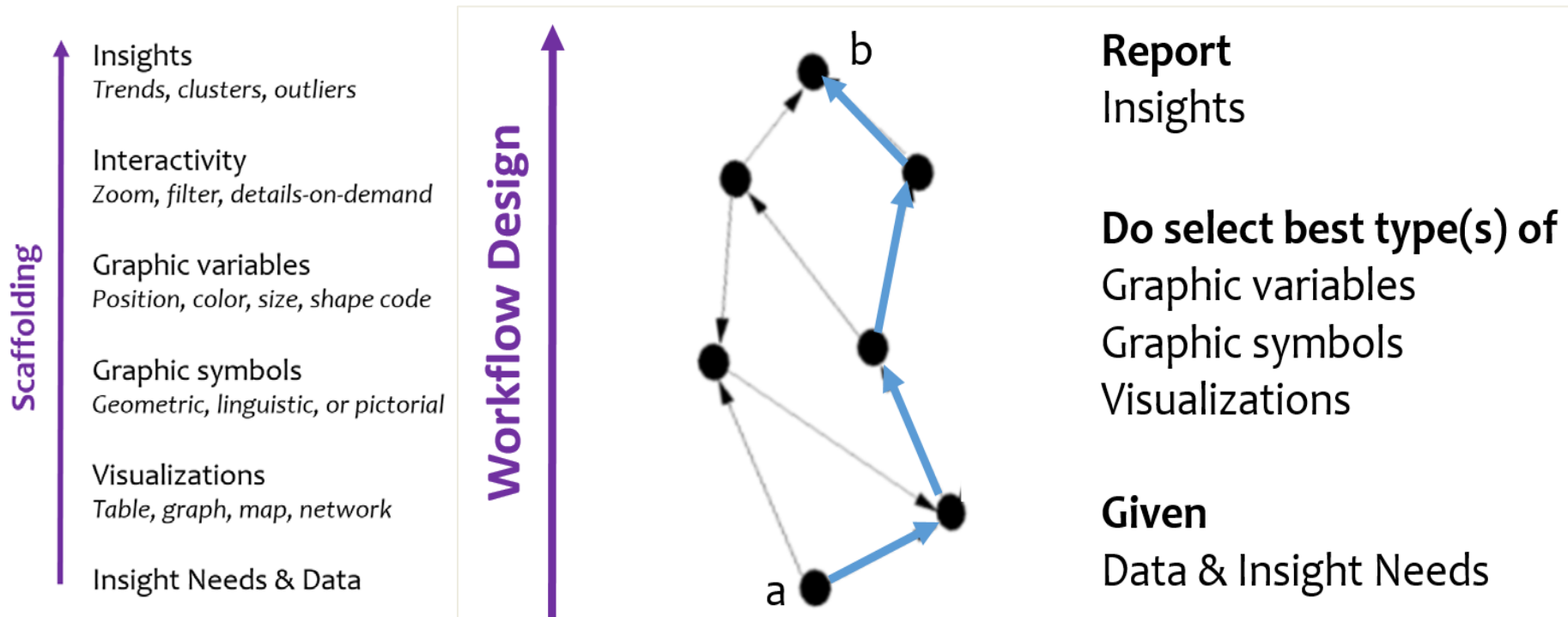
*Local*  
*similarity*



**Horizontal Transfer**

# Next Generation IVMOOC

Systematic study of how different student cohorts learn best—using **Learning Analytics** to optimize scaffolding and learning trajectories:

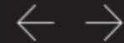


# MIT xPRO: Systems Engineering



FULL SCREEN

Four new courses, which will be delivered by MIT Professional Education via the edX platform, will marry the research and knowledge of MIT's world-renowned faculty with lessons and case studies in industry and government from Boeing and NASA professionals.



## MIT, Boeing, NASA, and edX to launch online architecture and systems engineering program

Four-course program will train professionals in latest practices on models and methods to manage complex systems

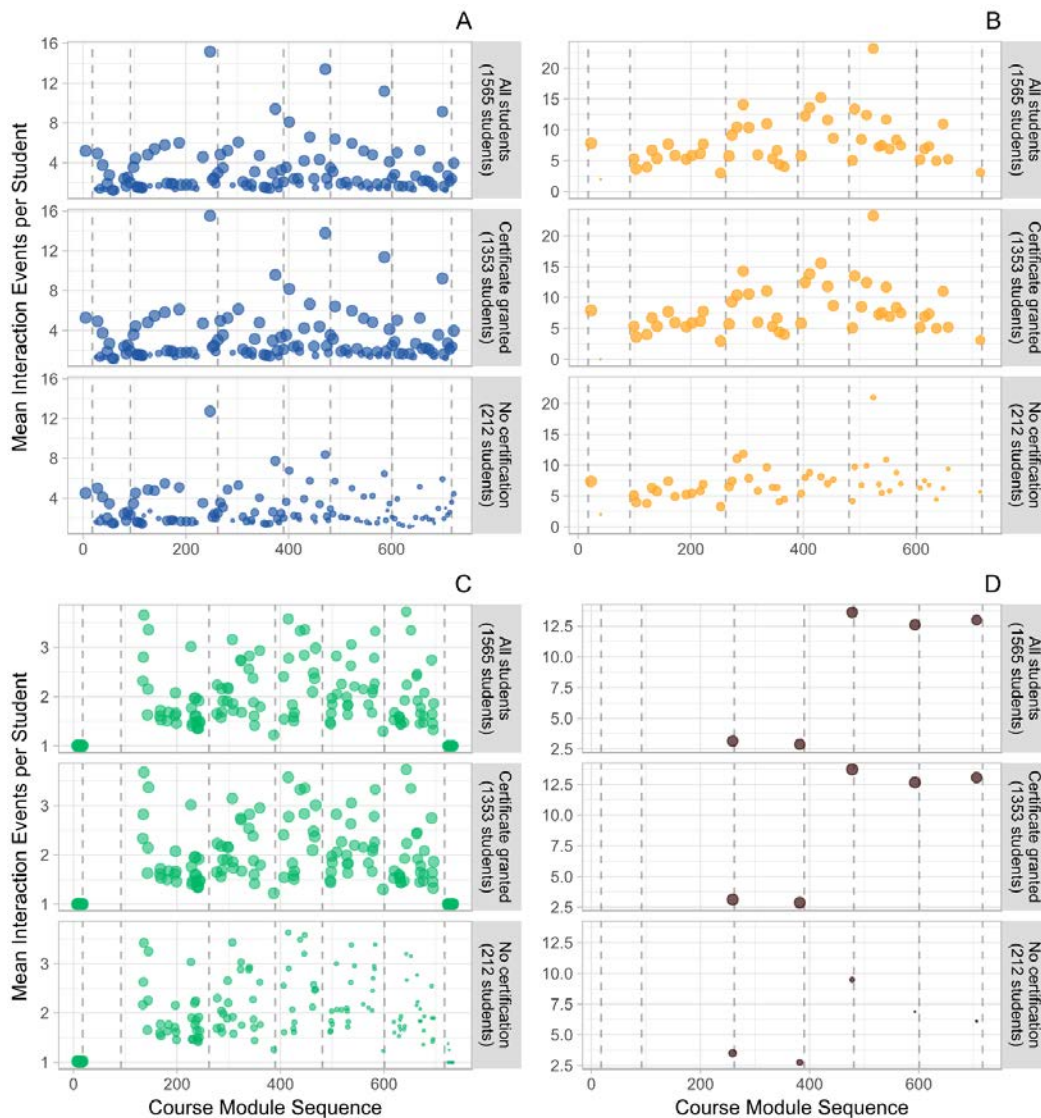
<https://sysengonline.mit.edu>

# Improving Return on Investment in Education: Measuring, Visualizing, and Optimizing Learner Trajectories

Michael C. Richey, Michael Ginda, Mark Cousino, Katy Börner

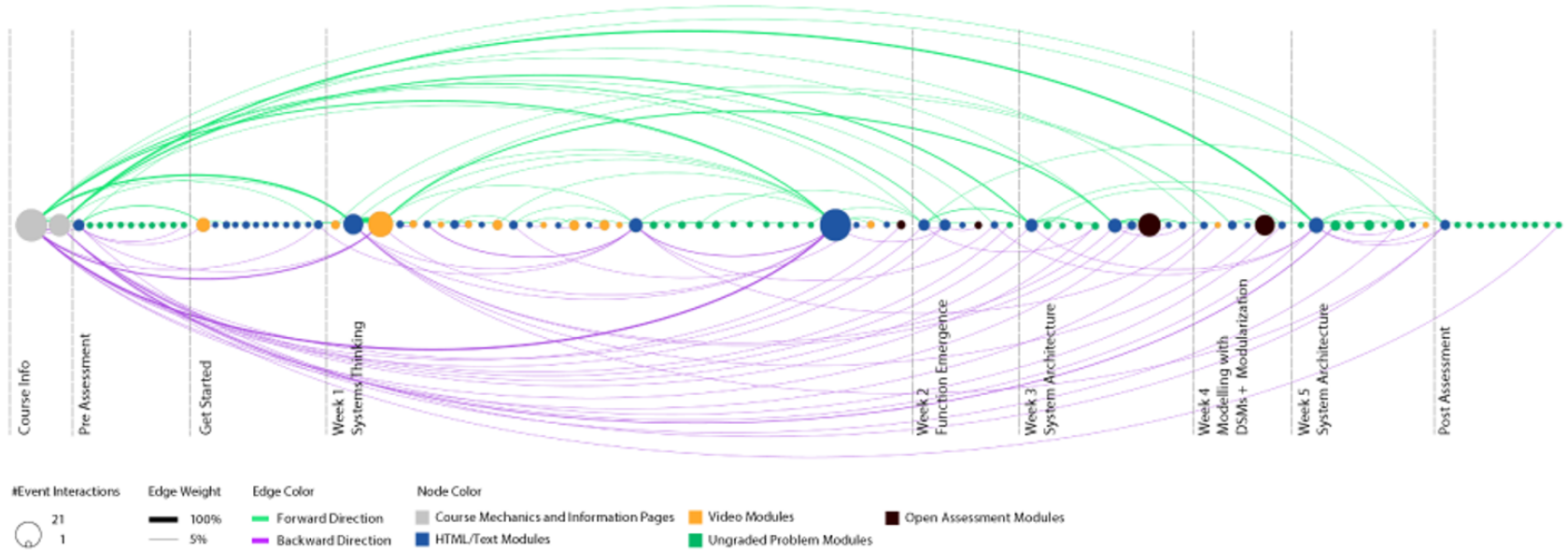
MIT xPRO Course  
“Architecture of Complex Systems” delivered via the edX platform in Fall 2016.  
**1,611 Boeing engineers** registered; 1,565 were active and generated nearly **31 million click event records** while accessing videos, projects, and assessments. Some students generated over 100,000 separate events.

All but 255 engineers passed the course, resulting in a completion rate of 84.1%.



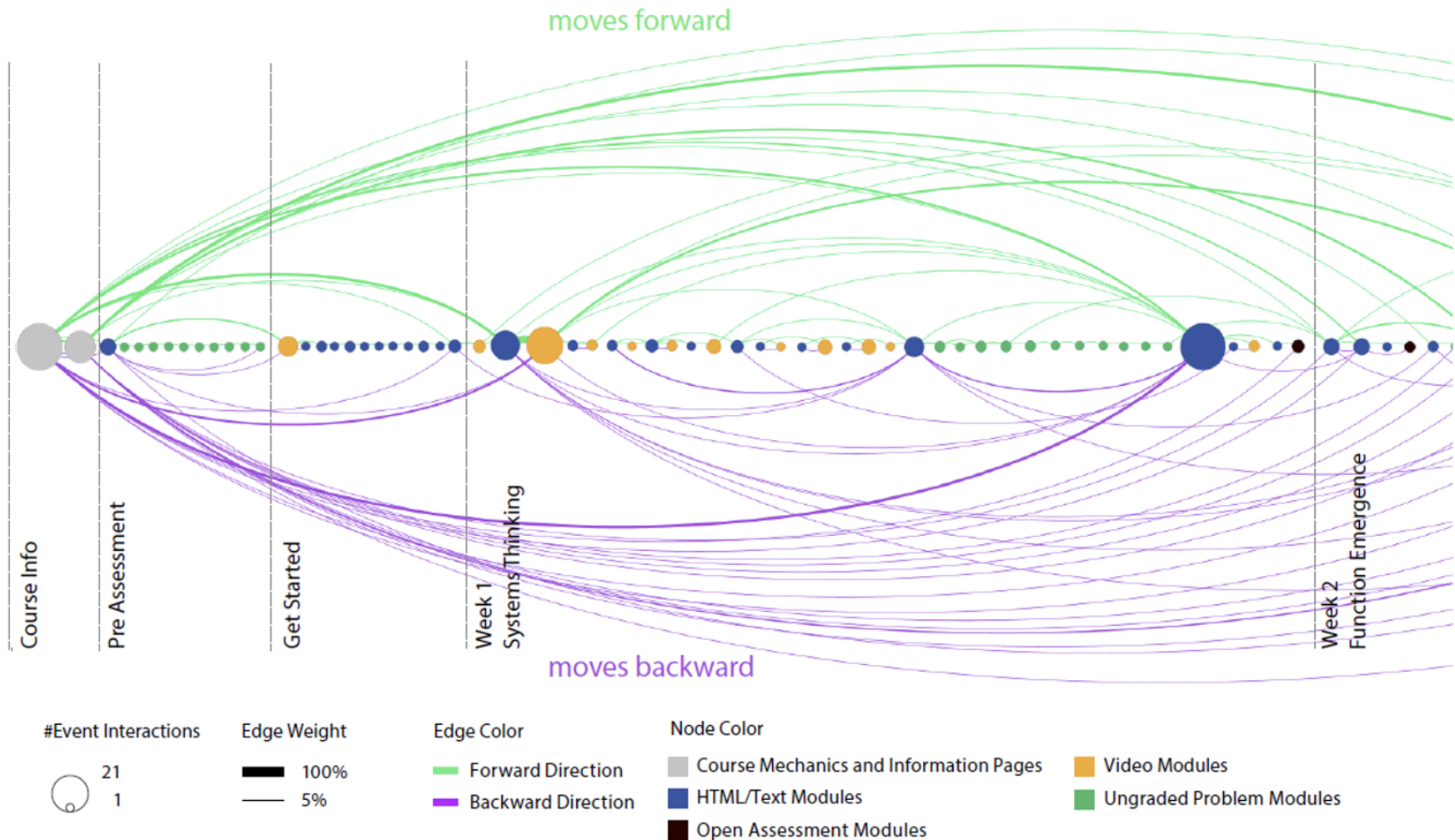
# Improving Return on Investment in Education: Measuring, Visualizing, and Optimizing Learner Trajectories

Michael C. Richey, Michael Ginda, Mark Cousino, Katy Börner



**Figure 1: Learner path overlaid on linear sequence of course modules.** Linear, temporal sequence of learning modules accessed by a high performing student plotted from left (first) to right (last) with dividing lines for pre and post but also week 1-5 modules.

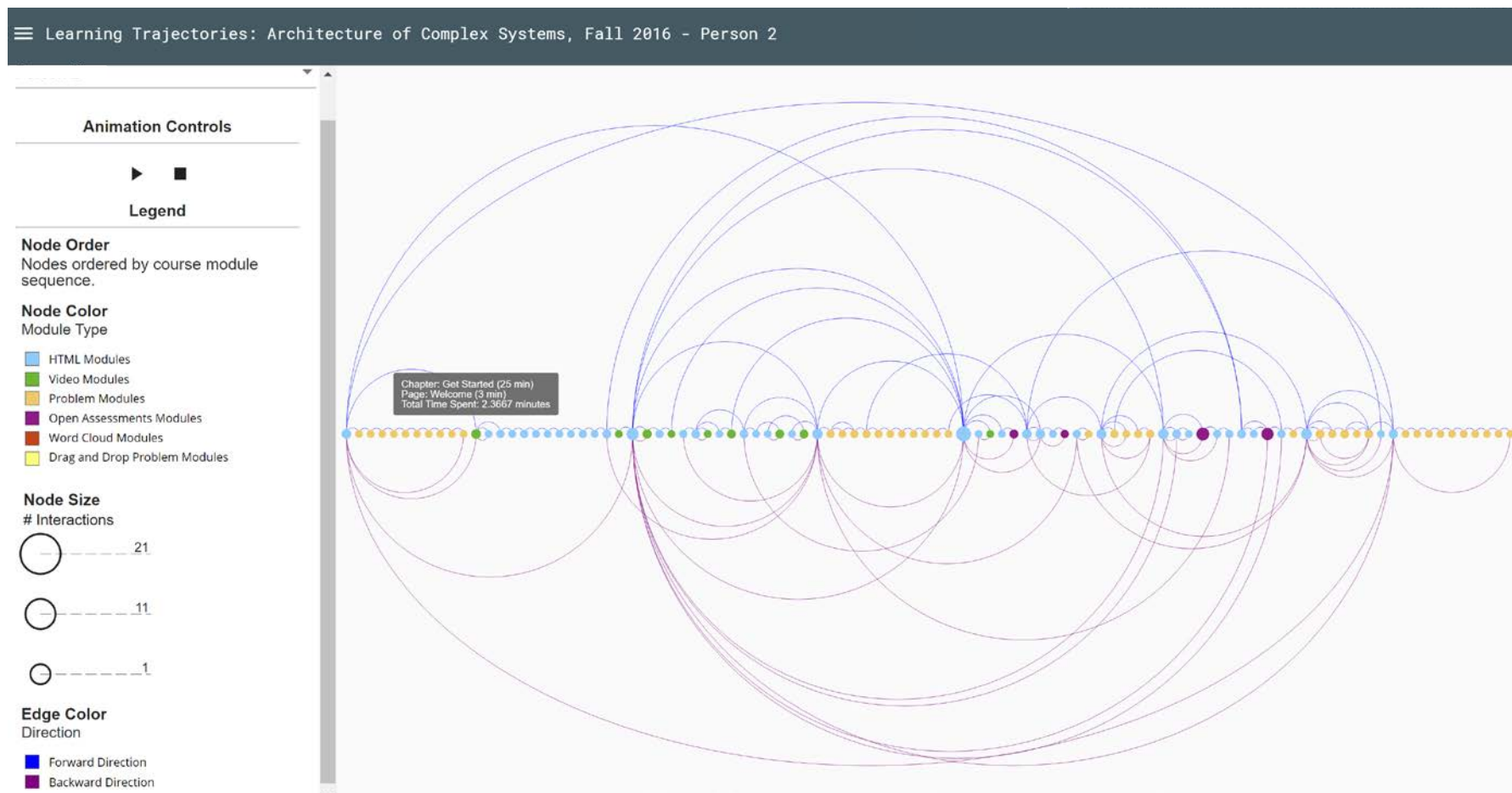




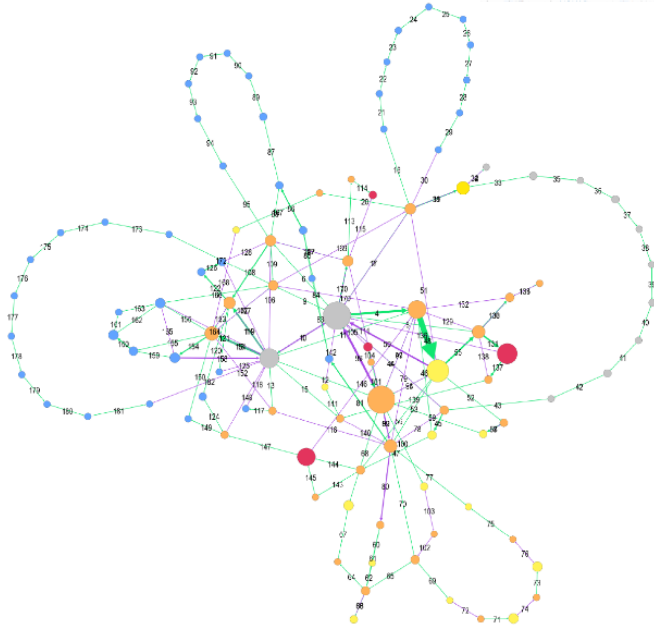
**Figure 2. Zoom into learner path overlaid on linear sequence of course modules.** Linear, temporal sequence of course modules used by a high performing student; plotted from left (first) to right (last) with dividing lines for different module sections.

# Improving Return on Investment in Education: Measuring, Visualizing, and Optimizing Learner Trajectories

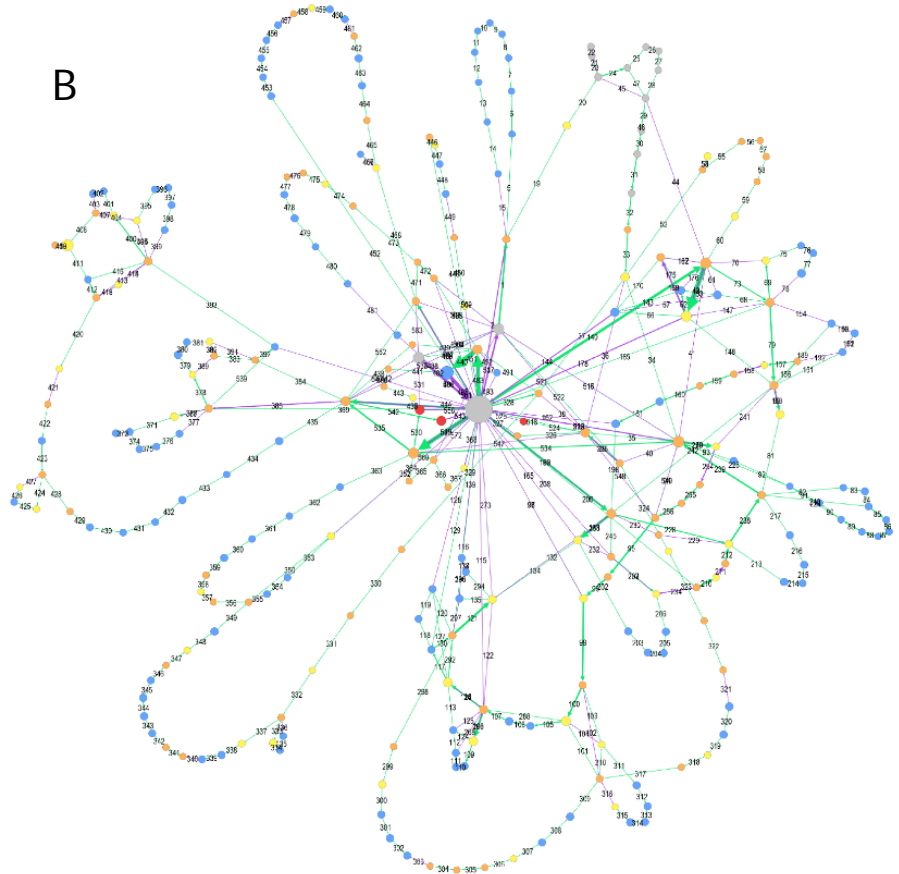
Michael C. Richey, Michael Ginda, Mark Cousino, Katy Börner



A



B



**Figure 3: Learner path overlaid on force-directed layout of used course modules.** Learner path of a students with high (left) and low (right) performance scores overlaid on force-directed layout of course modules.

# MIT xPRO: Additive Manufacturing



HOME

ENTERPRISE



## Additive Manufacturing for Innovative Design and Production

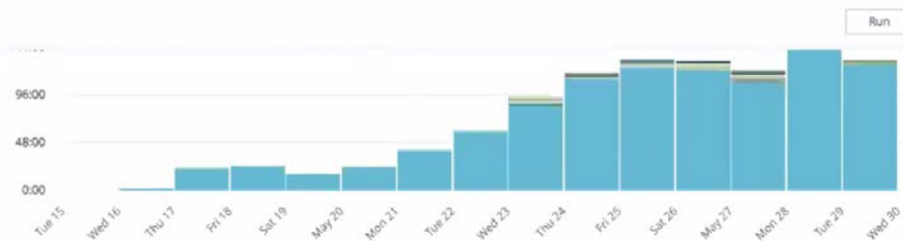
*A 9-week online course on creating new products,  
processes, and business models using 3D printing.*

<https://additivemanufacturing.mit.edu>

# Students use Onshape to practice what they learned

The screenshot shows the Onshape web interface. The top navigation bar includes 'Onshape', 'Activity', 'Documents' (selected), and 'Analytics'. A search bar is labeled 'Search in My Onshape'. There are buttons for 'App Store', 'Learning Center', and a user profile for 'Katy Borner'. A 'Create' button is visible on the left. The main area is titled 'My Onshape' and shows 'Last opened by me' with two 3D models: 'Optimized B-0128-g' and 'Bracket Optimization'. Below these is a table with columns for 'Name', 'Workspace', and 'Modified ...'. The table lists three folders: '[SUBMISSION] Graded Assignme...', '[SUBMISSION] Design Track I: To...', and 'Week 7-8 - Strategy Track'. A right-hand panel is titled 'My Onshape' and contains the text 'Select a document, folder or project to view its details'.

Name	Workspace	Modified ...	Modified ...
[SUBMISSION] Graded Assignme...		6:38 AM T...	James Si...
[SUBMISSION] Design Track I: To...		3:25 AM T...	Jessica P...
Week 7-8 - Strategy Track		1:08 AM Y...	Rebecca ...



# Students use Onshape to practice what they learned

The image displays two overlapping screenshots of the Onshape web application interface. The top screenshot shows the 'Documents' view for a user named 'Katy Borner'. It features a navigation menu on the left with options like 'My Onshape', 'Recently opened', 'Created by me', 'Shared with me', 'Teams', and 'Trash'. The main content area shows a list of documents under the heading 'Last opened by me', including 'Optimized B-0128-g' and 'Bracket Optimization'. A 'Create' button is visible at the top left, and search and navigation icons are at the top right.

The bottom screenshot shows the 'Analytics' view, specifically the 'Document Access' section. It displays a network graph titled 'Document network with modeling time'. The graph consists of numerous nodes and connecting lines. A legend on the right side of the graph identifies the nodes: blue circles for 'Document', green circles for 'User', red circles for 'Project', red dashed circles for 'Collapsed Project', blue lines for 'Document-User', and grey dashed lines for 'Not accessed'. The graph shows a dense network of connections between users and documents, with some nodes highlighted in red, indicating collapsed projects. A search bar is located at the top left of the graph area.

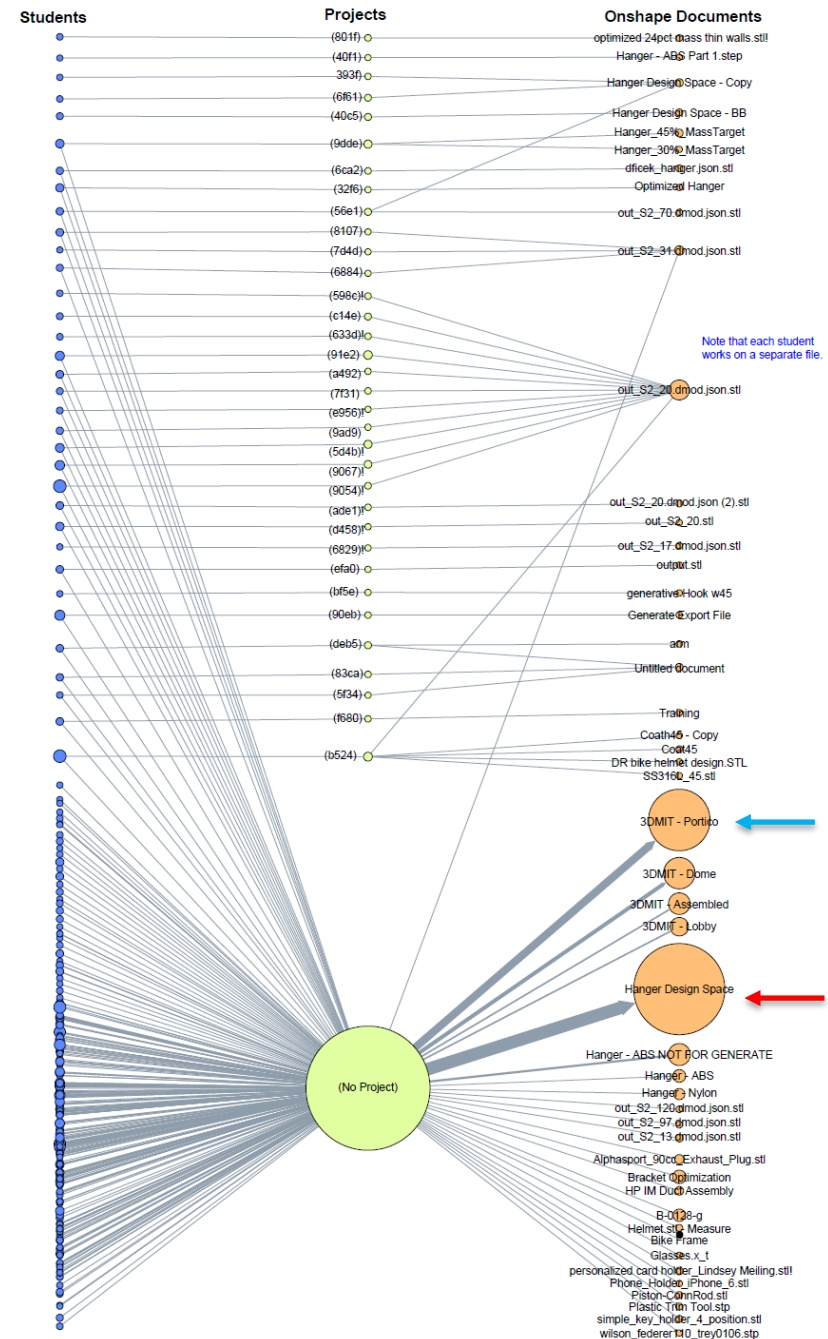
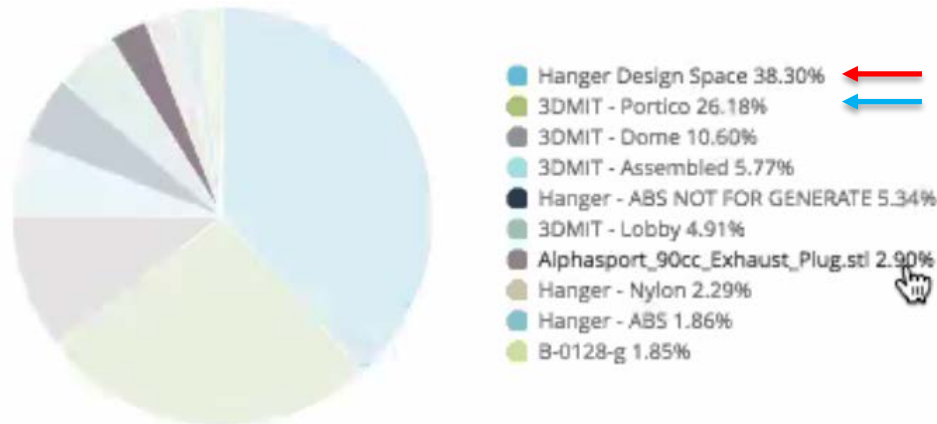
# Additive Manufacturing

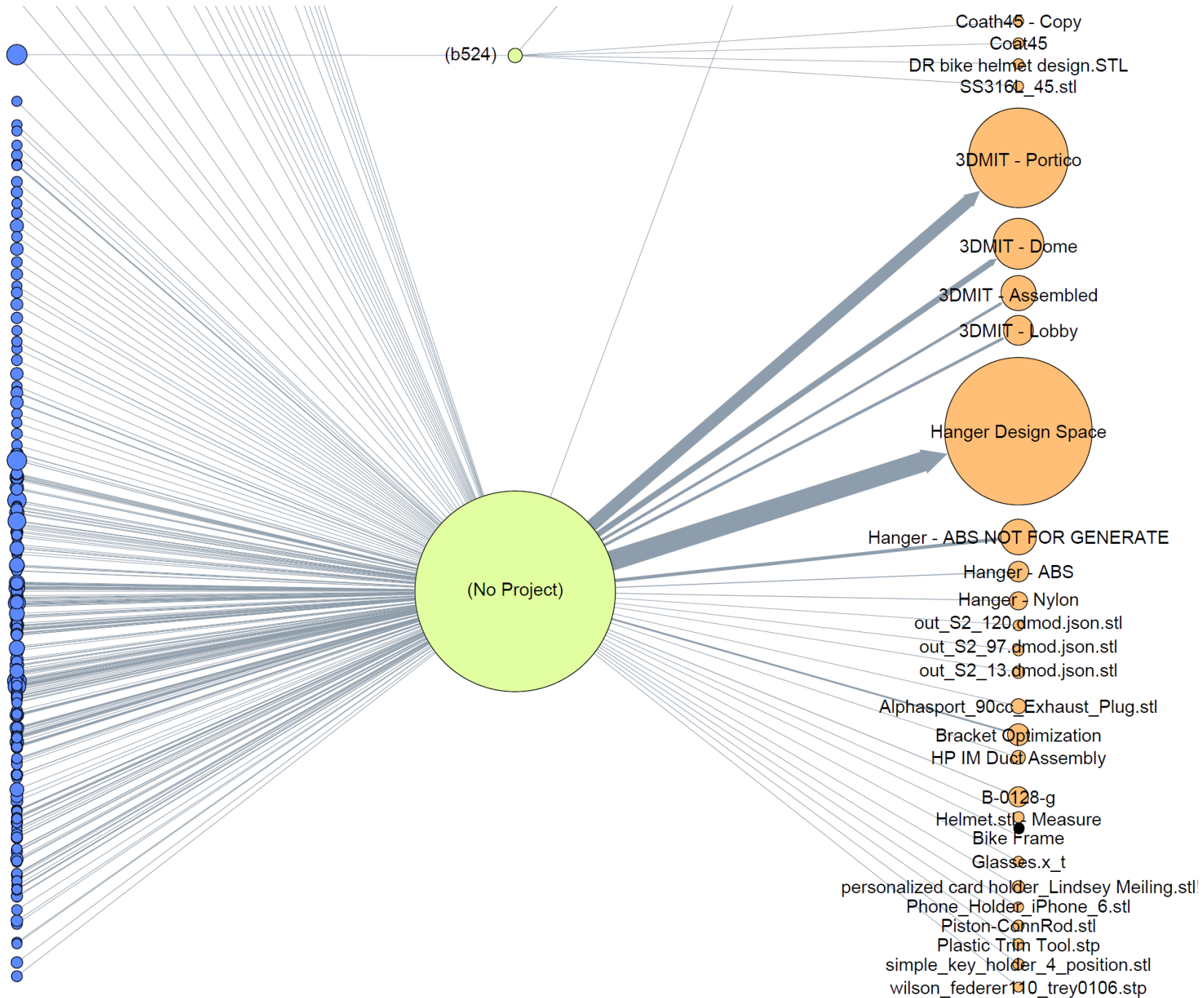
3-modal network of all Students (blue), Teams (green), Documents (orange) used in course by May 31, 2018.

Area size represents the total time associated with a given node in the modeling software.

- Top Student - 16.91 hours
- (b524) Project - 7.74 hours
- *Hanger Design Space* Document - 367.28 hours

Edge thickness denotes number of times an relationship occurred in the data.









Santa Fe Institute

**Embracing Human and Machine Intelligence Symbiosis**

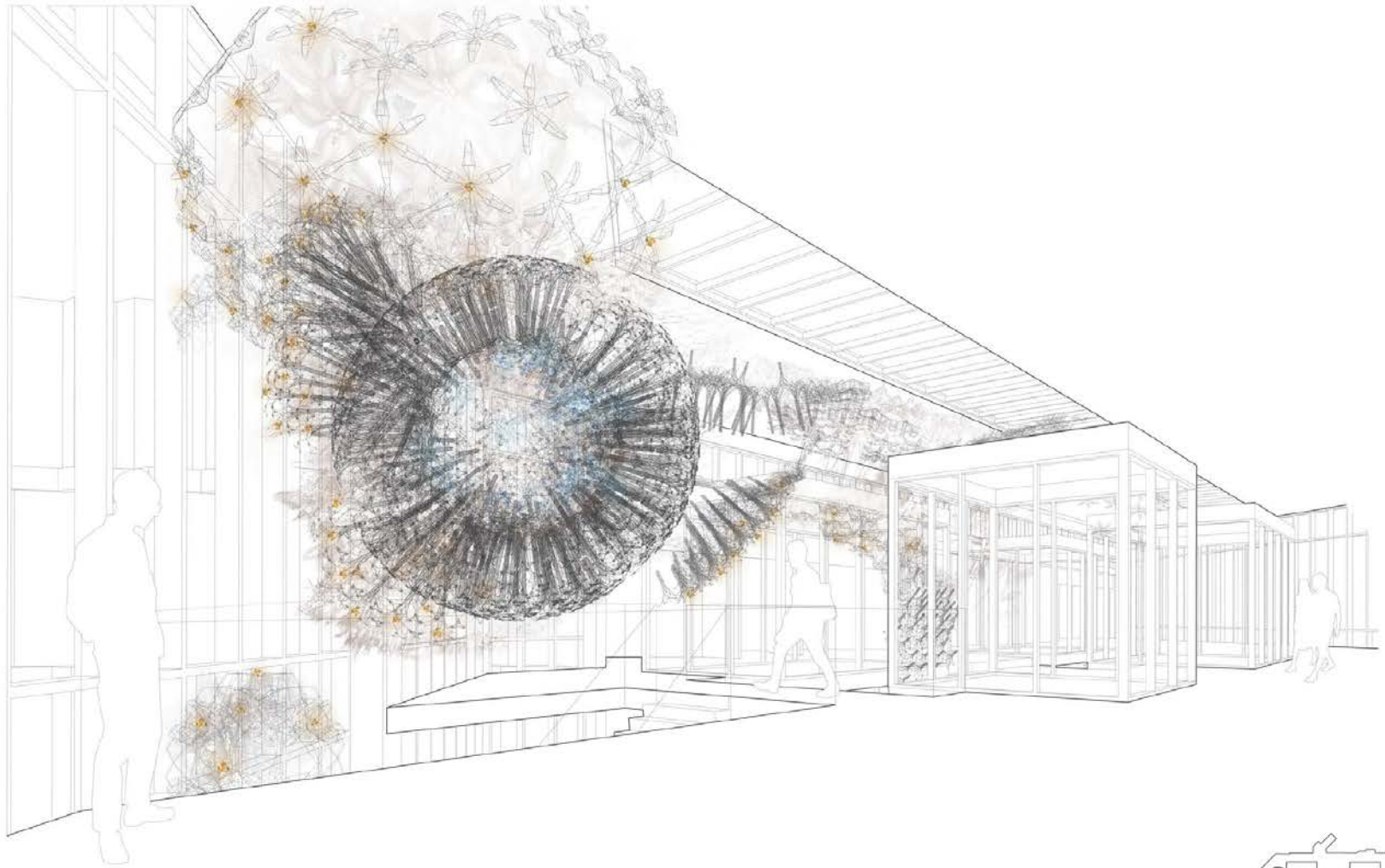
# Visualizing the Internet of Things (IoT)

Using large scale datasets, advanced data mining and visualization techniques, and substantial computing resources.



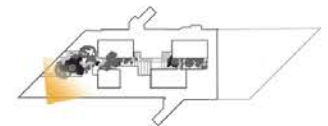
Work by Philip Beesley | [www.philipbeesley.ca](http://www.philipbeesley.ca) | [www.lasg.ca](http://www.lasg.ca)



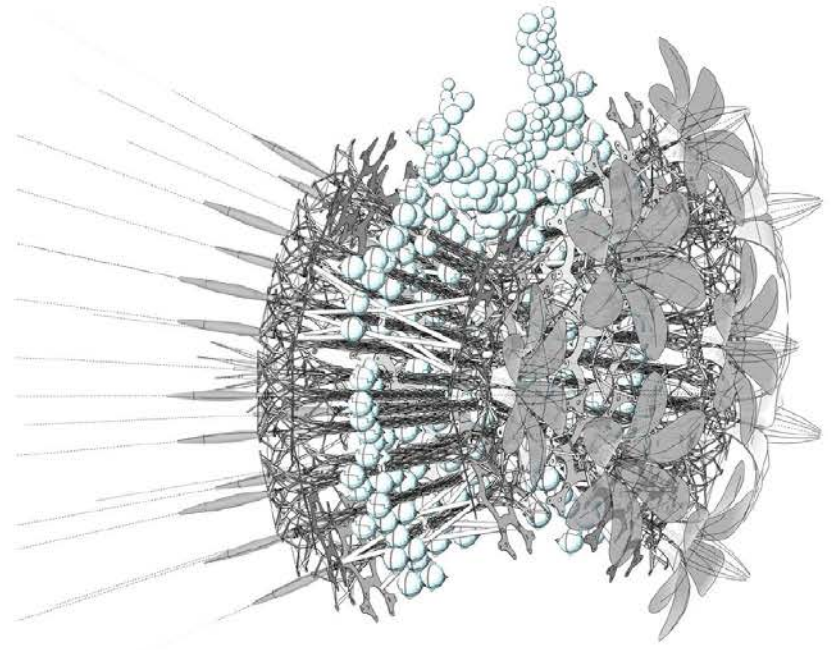
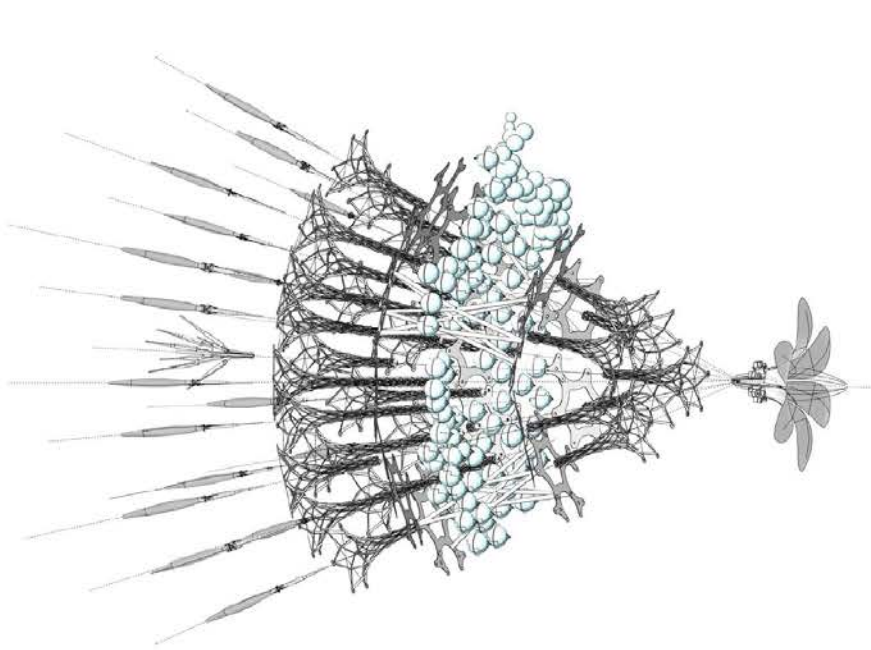


Luddy Hall Installation  
Indiana University Bloomington  
April 29 2017

UPPER ATRIUM



Philip Beesley • Living Architecture Systems



Luddy Hall Installation  
Indiana University Bloomington  
April 29 2017

ASSEMBLY SAMPLE

Philip Beesley • Living Architecture Systems





*Amatria Unveiled* by Andreas Bueckle et al. Data visualizations of sensor/actuator positions and types, energy and communication flows, and emergent behavior of smart environments.

# References

Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains**. In Blaise Cronin (Ed.), *ARIST*, Medford, NJ: Information Today, Volume 37, Chapter 5, pp. 179-255.

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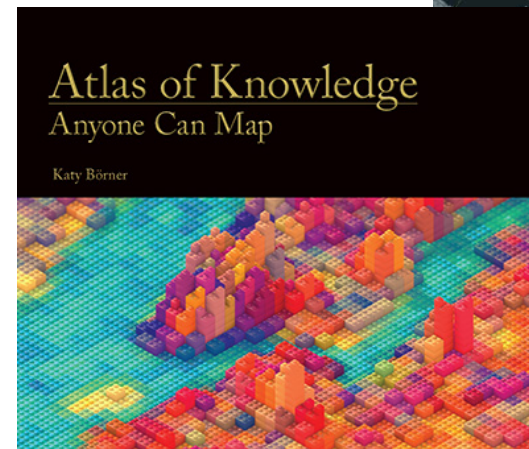
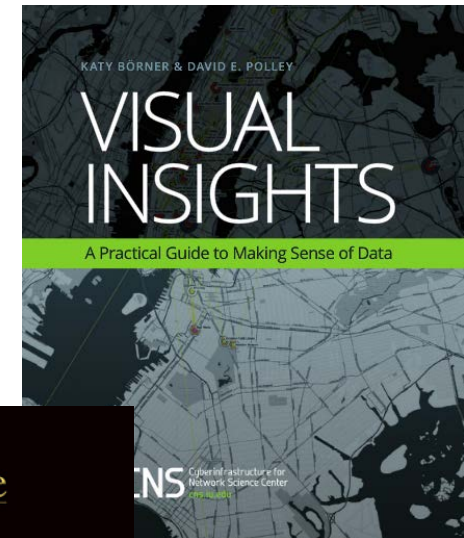
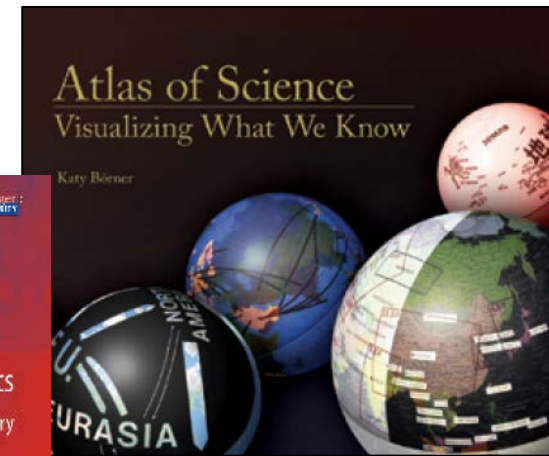
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